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## THE PROBLEM OF MARS.*

By HECTOR MACPHERSON.

Of the various planetary bodies in the Solar System, Mars has for the last hundred years made the strongest appeal to humanity at large. It is neither the nearest planet nor is it intrinsically the most important. The Moon is the nearest body of planetary dimensions, Venus is the most brilliant, while Jupiter is the giant of the Solar System. But Mars possesses an interest which these other bodies lack. It is generally conceded—and even Professor W. H. Pickering, whose researches have proved conclusively that a certain amount of change does go on in the Moon, would not deny the assertion—that the Moon is totally unfit to support any form of animal life; Jupiter, on the other hand, appears to be a world in a state of primeval chaos "without form and void", which, Professor Barnard holds will not be ready for its inhabitants until several millions of years have elapsed; while of Venus, owing to its dazzling brightness and its unfavorable position relative to the terrestrial observer, we know so little that even the length of its day is more or less an uncertain quantity. Mars, on the other hand, is a world which presents many analogies to the globe on which we live, and accordingly it has long been recognized that if life exists at the present time on any body of the Solar System outside our earth, it is most probably on Mars that it is to be found. And man has a craving for a sense of cosmical companionship. He is anxious to know, in the words of a popular writer, if "there are eyes to see and minds to think out in celestial space." Hence the interest with which the intelligent layman has followed the Martian controversy.

"Mankind," said Percival Lowell, "has to all intents and purposes been journeying Marsward through the years." And this is true. The history of Martian research—the gradual unveiling of the features of the planet's surface—has been the equivalent of a steady approach to our neighbor world. The history of Martian research is to be divided into three epochs:

(1). The study of Mars began—as did that of the other planetary bodies—with Galileo. In 1610 he turned his "Optic Tube" to the red planet, but his sole discovery was the Martian phase, the existence of which, of course, further confirmed the Copernican theory. Fontana

*Paper read before the Astronomical Class at Airdrie, Scotland, October 8, 1920.

of Naples, was the first observer to catch glimpses, in 1638, of dusky markings on the little red disc of Mars. In 1659 these were delineated in a rough sketch by Huyghens, made at 7 P. M. on November 28 of that year. From his study of the markings, he came to the conclusion that Mars rotated on its axis in about twenty-four hours. But this was never more than a suspicion to him, and it was G. D. Cassini who in 1666 made the first actual determination of the length of the planet's day, which he fixed at 24 hours 40 minutes—a remarkable approximation to the truth at that early stage of telescopic astronomy. At the favourable opposition of 1719, Maraldi—Cassini's nephew—confirmed his uncle's estimate and made an important discovery of his own. The determination of the axial period enabled him to fix the position of the poles; and at the poles he noted for the first time the two brilliant white spots which have since been known as the "polar caps".

(2). With the observations of Herschel, a new era opened in the study of Mars. This great genius left on practically every branch of observational astronomy the impress of his master mind; and the modern investigation of Mars dates from him. In 1777 he commenced observations and satisfied himself at an early stage that "the constant and determined shape" of the spots "as well as remarkable colour show them to be permanent and fastened to the body of the planet"—a conclusion which was challenged even by so painstaking an observer as Schröter, who held that the visible surface of the planet was a mere shell of drifting cloud. Herschel determined the rotation period with greater accuracy than Cassini had done; he also ascertained the axial inclination and equatorial diameter. He first drew attention to the variation in size of the polar caps. "I may well be permitted to surmise," he wrote in 1784, "that the bright polar spots are owing to the vivid reflection of light from frozen regions; and that the reduction of these spots is to be ascribed to their being exposed to the Sun". The general conclusion which he reached was that "the analogy between Mars and the earth is perhaps by far the greatest in the Solar System." "The planet," he concluded, "has a considerable but moderate atmosphere, so that its inhabitants probably enjoy a situation in many respects similar to ours."

Herschel's study of Mars was but an incident in his wider investigation of the structure of the universe; and accordingly he made no systematic series of drawings nor did he make any attempt to chart the planet. This was reserved for Beer and Mädler whose careful surveys extended over five oppositions from 1830 to 1839. Their telescope was one of four inches aperture and only the larger surface-features were charted by them. They established the fact that the dark markings actually belonged to the Martian surface, a fact which was still questioned at the time by some astronomers and they made a still more accurate determination of the rotation period. From 1840 to 1877 the planet was observed and sketched by a number of eminent

observers—Kaiser in Holland; Secchi in Italy; Dawes, Lockyer, Proctor, and Green in England. The beautiful drawings made by Green, who was an artist as well as an astronomer, are familiar to many of us from their inclusion in most popular works and text books on astronomy.

In 1870, in "Other Worlds than Ours" Proctor published a chart of Mars—based on drawings by Dawes—more elaborate than that of Beer and Mädler. The red and green areas were designated as continents and oceans respectively and names were fixed to them such as Herschel Continent, Dawes Ocean, Beer Sea, etc., etc. In his chapter on "Mars the Miniature of our Earth" Proctor summarized concisely the view of Mars current at the time—a world practically similar to the earth with continents and oceans, atmosphere and clouds; and he concluded—"shall we recognize in Mars all that makes our own world so well suited to our wants—land and water, mountain and valley, cloud and sunshine, rain and ice and snow, rivers and lakes, ocean-currents and wind-currents,—without believing further in the existence, either now, or in the past, or in the future, of many forms of life?"

(3). The favorable opposition of 1877, at which Mars approached the earth, cosmically speaking, very close, was signalised at the time by the sensational discovery by Hall at Washington of two tiny satellites of asteroidal size. But a still more important discovery was announced later, which marked the opening of the third epoch in Martian investigation. While executing a trigonometrical survey of the disc, Schiaparelli, of Milan, discovered that the continental areas were intersected by a number of straight dark lines, which he designated by the Italian word *canali*. It subsequently appeared that some of the more prominent of these markings had been seen by Dawes and Secchi, but had been simply classified as "straits." So it was reserved for the keen sight of Schiaparelli, in the clear air of Milan, to detect the remarkable network of lines the existence of which showed that Mars differed from no less than it resembled the earth.

In 1879 Schiaparelli again recognized the canals and in addition noticed that several of them had become double, and at the various oppositions up to 1890 he discovered still more of these enigmatical objects. These discoveries were made in the face of widespread scepticism. Indeed the story of the reception of the discovery is not a very creditable chapter in the history of science. For nine years only Schiaparelli could see the canals. In 1886, however, confirmation of their existence was obtained by Perrotin and Thollon, with the large refractor of the Nice Observatory; and other observers—Flammarion, Stanley Williams, W. H. Pickering, and many others—soon added their testimony to the existence of the canals.

In 1892 W. H. Pickering at the Harvard Station at Arequipa, in Peru, commenced the series of observations on Mars, which he has

continued more or less regularly up to the present time. He made two important discoveries. He detected, at the junctions of the canals, round spots which he called "lakes,"—an observation confirmed in 1894 by Lowell. He noticed, also, that the blue-green areas—hitherto believed to be oceans—were not free from the canaliform appearance, a conclusion verified by Barnard at the Lick Observatory and by Douglass at the Lowell Observatory two years later.

The latter-named institution was founded in 1894 by the late Professor Percival Lowell at Flagstaff, Arizona, for the specific purpose of planetary observation and in particular of elucidating the mystery of Mars. For twenty-two years, until his premature and lamented death in 1916, Lowell untiringly scrutinized Mars, following the planet for long periods before and after opposition. His observations and those of his successive assistants demonstrated the non-aqueous nature of the so-called seas. He discovered new canals, single and double, in large numbers, and his statistical studies indicated the development of the canal system in harmony with the seasons. Finally, his photographs in 1905 and subsequent oppositions went far to convince even the most sceptical of the objective reality of the canals. Since his death the study of Mars has gone forward at his observatory, but the most prominent figure in Martian astronomy is Professor W. H. Pickering, who from Mandeville, Jamaica, directs the activity of the international organization known as "The Associated Observers of Mars."

The earlier theories of the nature of the canals were mere guesses and have only a certain historical interest. For instance, it was suggested by some that the canals were chains of mountains running over land and sea; and by others that they represented cracks of enormous breadth and width. More credible was the suggestion advanced by Schiaparelli, their discoverer—that the canals represent waterways lined on either side by banks of vegetation. This view was developed by W. H. Pickering, who suggested that the dark lines visible as canals are not the canals themselves—which are much too small to be seen—but the fertilized ground on either side of them. This idea formed an integral part of Lowell's theories on the constitution of Mars.

Lowell's hypothesis—first put forward in 1895 in his book "Mars" and developed in his later works—is too well known to require explanation in detail. In his view—which he maintained more strongly at the close than at the beginning of his work—intelligent life is the key to the mystery of Mars. Mars is a smaller, and therefore on any evolutionary scheme, an older world than our own. The observational work of Schiaparelli threw grave doubt on the existence of oceans, while the discovery by Pickering, confirmed by Lowell and Douglass, of canals in the blue-green areas finally disposed of the oceanic hypothesis. That the reddish-ochre areas are desert land and the blue-green areas tracts of vegetation forms the basis of Lowell's hypothesis. Next,

Lowell showed that the canal-system developed in dependence on the snow-caps; obviously, as might be expected from the thinness and clearness of the Martian atmosphere and its freedom from aqueous vapour, the water-supply of the planet is dependent on the melting of the snow-fields in early summer. As the cap melts, the canals darken and a wave of verdure passes towards the equator and into the opposite hemisphere, and as Lowell's statistical work in 1903 showed "the transference of water takes place in the face of gravity. Of its own accord it would not move from the pole to the equator. Now, as it does flow towards the equator, and with a remarkably steady progression too, the inference seems inevitable that it has been carried thither by artificial means." The round spots at the junctions of the canals—discovered by Pickering—were termed by Lowell "oases" and on his hypothesis they represent the centres of population where the inhabitants driven from the desert lands by scarcity of water cluster about the ground artificially fertilized. In a lecture, delivered a few months before his lamented death, Lowell claimed that "since the theory of intelligent life was first enunciated twenty-one years ago, every new fact discovered has been found to be accordant with it. Not a single thing has been detected which it does not explain."

When the theory was first put forward it was received with general ridicule. Schiaparelli, when the idea of intelligent agency began to be mooted, was careful to say that such a supposition "involves no impossibility." In 1897 he said of the canal-system—"the whole arrangement presents an indescribable simplicity and symmetry which cannot possibly be the work of chance," and on December 4, 1904, he wrote to Lowell, "your theory of vegetation becomes more and more probable". But the great majority of professional astronomers were highly sceptical. At first Lowell's hypothesis was generally ridiculed. Later when it was seen to be too formidable to be laughed out of court, another hypothesis was formulated and was, for years, widely accepted as the last word on Martian astronomy.

Ever since the canals were discovered there have been those who have been sceptical as to their objective existence. As far back as 1891 Mr. E. W. Maunder of Greenwich came to the conclusion that "in all probability the canals of Mars were simply the summation of a complexity of detail far too minute to be discerned." Cerulli of Teramo, in 1897, came to a similar conclusion. "These lines," he said, "are formed by the eye which utilizes the dark elements which it finds along certain directions. A large number of these elements forms a broad band. A smaller number of them gives rise to a narrow line." A number of experiments were made by Mr. Maunder in 1902-03 on the pupils of Greenwich Hospital School, a number of whom were asked to make copies of drawings of Mars on which the canal system was not represented. As many of the boys drew straight lines instead of irregular dots, Mr. Maunder concluded that the illusion theory was

finally proved. And when Simon Newcomb lent the great weight of his authority to the theory, the astronomical world in general accepted it. What those who accepted the theory forgot was that despite the mighty intellect of Newcomb and the outstanding gifts of Maunder, neither had at any time made a prolonged study of Mars. In addition, it was overlooked that Maunder, in a poor climate, was ill qualified to refute the views of Lowell, who observed Mars for months at a time with one of the largest telescopes under the most favorable skies in the world.

Lowell replied sarcastically to the "small boy" theory, as he called the hypothesis of Maunder. "It asserts," he said, "that because of the tendency of the human eye to connect well-seen points by imaginary lines, therefore those on Mars are of this class; which is like saying that because a man may see stars without looking at the heavens, therefore those in the sky do not exist. The parallel is not simply for illustration; it is exact, for the nervous action of the optic lobes will similarly cause any one to see faint points of light in a darkened field of vision, and the whole art of the observer consists in distinguishing which of these phenomena are objective and which are not. So with these lines. A little more experience than the boys possessed would have permitted of parting the true lines from the false." More potent than his arguments was his success in photographing the principal canals at the opposition of 1905. "The camera does not agree with the arm-chair critics of the canals," he wrote in a letter addressed to me at the time, "but will have it that these markings are lines." The supporters of the illusion theory, however, would not admit their defeat. In 1910 Maunder maintained that "the granular structure of the plate acts as a third factor in reducing irregularities and simplifying details; a third factor in producing the two simplest types of form, the straight line and the circular spot." In 1913, Antoniadi, of Meudon Observatory, near Paris, in a paper published in POPULAR ASTRONOMY, confidently declared that "the astronomer of the future will sneer at these wonders; and the canal fallacy after retarding progress for a third of a century is doomed to be relegated into the myths of the past." In this amazing paper—for amazing it can only be called, amazing in its truculence and its prejudice—Antoniadi spoke somewhat patronisingly of Schiaparelli's "errors of judgment." He never once mentioned Lowell by name and utterly ignored his statistical studies and his Martian photographs. The paper was effectively disposed of by E. C. Slipher in the following year. He truly remarked that "it is not surprising" that Antoniadi "does not see these markings when it is remembered that he only occasionally observes the planet at the Meudon Observatory (533 feet above sea level) and he adds to the disadvantages of the atmosphere those caused by failing to use a dark glass or shade over the eye-piece, and also by using the full aperture of the 33-inch objective. His published drawings bear striking evidence that

he sees the planet poorly, not only on account of the absence of fine detail but because of the ill-defined appearance of the coast-lines and other markings along the dark regions . . . So the importance of his remarks is more apparent than real."

The principal weakness in the various illusion theories has always been the fact that they have been advanced and maintained by those who were not in the front rank of observers of Mars. Newcomb, Maunder, Cerulli, Jacoby and others were or are highly distinguished along their own lines; but they were not competent to speak with authority on the problem of the canals. Only those whose studies have extended over many years can speak with high authority. As a matter of fact, Lowell was perhaps not far wrong when he assigned as a reason for this extraordinarily conservative and sceptical attitude the reluctance in certain intellectual circles—not only theological, but scientific—to admit the existence of life on another world. "Like the savage," Lowell wrote in 1895, "who fears nothing so much as a strange man, like Crusoe who grows pale at the sight of footprints not his own, the civilized thinker instinctively turns from the thought of mind other than the one he himself knows. To admit into his conception of the Cosmos other finite minds as factors has in it something of the weird. Any hypothesis to explain the facts no matter how improbable or even palpably absurd it be, is better than this. Snow-caps of carbonic acid gas, a planet cracked in a positively monomaniacal manner, meteors ploughing tracks across its surface with such mathematical precision that they must have been educated to the performance, and so forth and so on, in hypothesis each more astounding than its predecessor commend themselves to man if only by such means he may escape the admission of anything approaching his kind."

Very different has been the attitude of Professor W. H. Pickering. He has, it is true, not definitely adopted Lowell's theory; but his careful consideration of that and other hypotheses has been characterised by fairness and open-mindedness. In the course of his studies, Pickering has advanced and supported more than one tentative hypothesis. In his sixth "Report on Mars," in 1915, Pickering considered not only Lowell's theory but suggested two variations of it; (1) that the canals consist of a growth of dark vegetation like trees or bushes on plains of a lighter color, being supported by water artificially drawn from the natural aerial circulation of the planet. (2) that fogs might be artificially localized on certain selected regions. "It is known as a laboratory experiment that fog can be induced to form in a saturated atmosphere if furnished with a sufficient number of minute solid nuclei on which it may condense. It is suggested that it might be practical to do this either by electrifying the air in certain regions, night after night, or by some such similar means upon a large scale on Mars."

In 1918 Pickering put forward a new provisional explanation of the canals which he called "the aerial deposition theory." With character-

istic modesty, Professor Pickering offered this theory "to the astronomical world and particularly to the meteorologists for their criticisms and suggestions." On this theory "the function of the so-called canals" is "to furnish a substitute for our oceans and to furnish by evaporation during the Martian summer a steady and continuous supply of water after that derived from the northern snows has appreciably diminished." The water from the melting polar cap according to this theory is deposited in the three main depressions on its borders and is then evaporated and carried by the aerial circulation of the planet along the curved lines which in accordance with Ferrel's theory of the circulation of the winds it must necessarily follow. The storm clouds which in that rare atmosphere should condense at night, would in this manner carry the water and deposit it in the elongated marshes which we see and call canals."

It is difficult to see how this theory can possibly explain the varied phenomena of the Martian surface—canals, single and double, oases, carets and "fontes." Nor does it give a satisfactory explanation of the north and south polar bands which, in Professor Pickering's own view, are the indication and mark left by the "auxiliary mechanism" which transports the water from the north polar cap to the southern hemisphere. Indeed, Pickering himself, in 1915, wrote of these bands—"We seem driven back to intelligent direction. There really seems to be no other explanation for them, with the information at present at our disposal."

It seems to me, after careful and impartial study of all the theories that Lowell's hypothesis of intelligent life is the most probable. The balance of evidence is distinctly in its favor. It may be modified as time goes on—perhaps in the direction of Pickering's suggestion of the artificial localization of fogs. But the important fact about the theory is that it explains the various changing phenomena of the planet's surface on one assumption—that intelligent life exists on Mars. It cannot be said that the assumption is either extravagant or fantastic.

It has been asserted, however, that theoretical considerations rule out the possibility of life of high intelligence. Maunder calculates that the mean temperature of Mars is probably near 0° F.—considerably below freezing-point. If this were actually true—if Mars only received three-sevenths of the heat received by the earth—then life of an advanced type on its surface would be impossible. But the surface-features of the planet—the presence of vegetation and of polar snows, indicating the existence of water—show that the temperature is considerably higher than that derived from consideration of distances from the sun alone. Efforts used to be made to show that the polar caps were composed not of snow and ice, but of carbonic acid gas, and it was also maintained that water was non-existent in the Martian atmosphere. Some support was given to such a contention when Campbell at the Lick Observatory, failed to confirm the earlier conclusions of Hug-

gins and Vogel as to the presence of lines of water-vapour in the spectrum of Mars. In 1908, however, the question was finally set at rest by V. M. Slipher's definite identification of the lines of water-vapour in the planet's spectrum. The temperature, therefore, must be higher than theoretical conclusions based on distance alone would allow.

In his last book, "Mars as the Abode of Life," Lowell, from a theoretical conclusion based not only on distance but on the transparency of the Martian atmosphere, estimated the mean temperature of the planet to be about 48° F. Obviously this fits in much better with the actual appearance of the planet than the colder ones. So we need not hesitate to accept Lowell's conclusion that "the mean climate warmth of the two planets is not very unlike, and far within the possibilities of life for both."

If the hypothesis of intelligent life on Mars be true, many questions at once occur to our minds as to the condition—physical, intellectual and spiritual—of these denizens of another world. "What we see," said Lowell, "hints at the existence of beings who are in advance of, not behind us, in the journey of life." Whether or not signals from these beings will ever be received here on earth we do not know. It is not impossible, however, if science has made progress on Mars comparable with its progress here. But the configuration of the planet does indicate that in one direction at least the Martians are far in advance of us. The pressing need of water has probably forced the various races of that world into closer unity for a common end, and has compelled them to get beyond the stage of war and conflict. If the disc of Mars really speaks to us of another humanity out there in space, it is a humanity living in peace and concord. The city-states of Mars—which appear to us the little round "oases" at the junctions of the canals—would appear to be linked together in a veritable League of Nations. And by a strange paradox, it would seem to be on the so-called planet of war, that the prophetic vision finds its fulfilment—"Nation shall not lift up sword against nation, neither shall they learn war any more."

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## REPORT OF THE AMERICAN METEOR SOCIETY FOR 1920

By CHAS. P. OLIVIER.

During 1920 the number of observations of meteors, sent in to the writer, was 650 made on 35 nights by ten persons. The observers were N. P. Ball, Mrs. Grace Bessey, Miss H. M. Hempel, R. McIntosh, John Koep, C. P. Olivier, A. L. Peck, J. L. Peters, R. O. Suter, Jr., and T. K. Tomkins. Mr. N. P. Ball, of Colton, Calif., reported 356

or more than one-half of the total. The small number observed was due first to our having lost several of our best members, and secondly to cloudy weather at the maxima of most of the principal showers. However, in addition, during the year several reports of brilliant meteors or meteorites were kindly sent in by the Chief of the Weather Bureau, who has been taking an active interest in our work. A record of telescopic meteors, seen in all telescopes of this observatory, was also kept.

Despite the poor showing as to observations, two important events occurred for the A. M. S. during 1920. First we have secured the hearty co-operation of the American Association of Variable Star Observers in helping to obtain the magnitudes of telescopic meteors. Secondly the publication containing the results of the 22,000 observations, made by our members from 1914 to 1918 inclusive, is now in press and the first proofs have been corrected. All members may expect their personal copies in the next few weeks. As this publication will contain more observations of meteors, discussed in a scientific manner, than any that has ever appeared, it is hoped that its issue will revive the interest of our members and attract others to join in our work. The long delay, while regrettable, has permitted the publication to become more complete. It will appear as Part 7, Vol. II, *Publications of the Leander McCormick Observatory*.

It is of interest to announce that Mr. John Koep of Wisconsin, who was our most industrious member, is now on the staff of this observatory. He was appointed to a student fellowship in recognition of his excellent work on meteors. The writer plans, with his assistance, to undertake in the near future some new experiments in meteor observing which he hopes will be of value.

A cordial invitation is again issued to all interested in meteors to join in the work of the A. M. S. and full information will be sent on application.

Leander McCormick Observatory, University of Virginia, Va.
1921 February 17.

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## CHRONOGRAPHIC DETERMINATION OF THE LAG BETWEEN THE ARLINGTON AND THE ANNAPOLIS RADIO TIME SIGNALS.

By FRANK D. URIE.

The transmitting clock of the U. S. Naval Observatory sends time signals by wire to Arlington, Radio, Va., and to Annapolis, Md. At each of these naval radio stations the wire signals are automatically converted into radio signals. As it is possible for us at Elgin, Ill., to obtain excellent chronographic records of both the Arlington and the

Annapolis radio time signals, I decided to make a determination of the lag between them.

The apparatus used at the Elgin Observatory for recording Arlington and Annapolis is essentially the same as described at the 1915 meeting of the American Astronomical Society (POPULAR ASTRONOMY Vol. XXIII, No. 9, November, 1915). The crystal detector has been replaced by the more sensitive oscillating vacuum tube, and the original 4-step amplifier has been superceded by a 3-step amplifier of modern design. The aerial used in the present investigation consisted of a single wire 180 ft. long and 30 ft. high. The apparatus is entirely automatic in operation, the incoming radio signals controlling the movement of the chronograph pen.

The following plan was used in obtaining the chronograph records. The mean time clock Riefler No. 224 of the Elgin Observatory was recorded on the chronograph sheet for several minutes before signal time, and was cut out of circuit during signal time, in order not to complicate the sheet. The receiving apparatus was then tuned to the Annapolis wave-length (17,000 meters) and as many seconds as possible were recorded on the chronograph during the first half of the signal. The receiving apparatus was then tuned to the Arlington wave-length (2,500 meters) and as many seconds as possible were recorded during the remainder of the signal. Riefler No. 224 was then again recorded for several minutes. The measurement of the sheet was accomplished by drawing straight lines between the same seconds of Riefler No. 224 and measuring the difference (S—No. 224) between Annapolis and Riefler No. 224, and also the difference (A—No. 224) between Arlington and Riefler No. 224. Finally, the difference (A—S) between these two quantities is the lag of Arlington on Annapolis. The following table contains the complete data of the determination.

| 1921 | | Number of Comparisons with NSS | with NAA | (S—#224) | (A—#224) | Lag (A—S) |
|---|---|---|---|---|---|---|
| January 6, Thursday, | Noon. | 71 | 37 | —0.298 | —0.274 | +0.024 |
| 7, Friday, | Noon. | 34 | 10 | —0.178 | —0.160 | +0.018 |
| 8, Saturday, | Noon. | 25 | 81 | —0.168 | —0.146 | +0.022 |
| 8, Saturday, | 10 P. M. | 14 | 47 | —0.176 | —0.156 | +0.020 |

The average of the above 4 determinations gives the lag of Arlington on Annapolis as +0.021 sec. ±0.001 sec.

January 11, 1921.

## A FEW REMARKS ON "DARK LIGHTNING."

By FERDINAND ELLERMAN.

In the October 1918 number of *Camera Craft*, the accompanying photograms of lightning were used to illustrate a short article on "dark

lightning". A few responses were received, but none offered to give a satisfactory explanation of such a mixture of dark and bright lightning flashes as are grouped together in Fig. 4.

These photograms were made in the ordinary manner of exposing the plate to a number of flashes before inserting the slide, simply to get a number on the plate instead of only one. Lightning storms are not common in California, but this particular one, June 30th-July 1st, 1918, was the most violent the writer has had the pleasure of experiencing. It began about 10 o'clock in the evening and lasted till 5 o'clock the next morning. At one time, five distinct centers of lightning discharges were visible from Mount Wilson. It is due to the lack of opportunity to photograph lightning here, that the writer was not prepared to make the proper experiments for obtaining plates which might give a more satisfactory clue as to the explanation of the photographic phenomena of "dark lightning", and why it shows so much more marked on some plates than on others. That there is no such thing in reality as "dark lightning" we are sure, and the four illustrations are reproduced to show how differently the plates are affected at different times.

In Fig. 1,* we have four distinct flashes, with brilliantly illuminated background, but not a single case of reversal, or "dark lightning." In Fig. 2, there are a few branches which are dark, while in Fig. 3, we have two closeup views of flashes, whose branches all show dark edges and terminate in dark ends. There is also a hazy dark border along the main flashes. There are also two bright flashes near the middle of the plate which show no dark branches, while a faint dark flash is evident between them. In Fig. 4 we have a most extraordinary condition. Here are five distinct flashes with their branches, two of which are bright their entire length, but having dark branches, two which begin dark and end bright with dark margins, and one which begins faint with dark edges, becomes almost dark, then brighter again. One of the first mentioned bright flashes has no dark margin, although its branches are as dark as those of any of the others. It will be noticed that even the illumination of the low fog as the flashes passed through, is reversed.

†The Clayden effect, which is produced when an exposure of very short duration is afterwards illuminated with a feebler light source of longer duration, will cause a reversal of the image. If a spectrum of a single spark is exposed on a photographic plate, and the plate then exposed to a candle light sufficiently long to fog the plate, a positive of the spectrum will be obtained if the two exposure times are correct. If the spark spectrum exposure is very strong a partial reversal only is obtained, and the stronger lines are black with clear edges, while the

*See Frontispiece for Fig. 1 and Fig. 2.
†R. W. Wood, *Astrophysical Journal* **17**, p. 361, June, 1903.

PLATE X

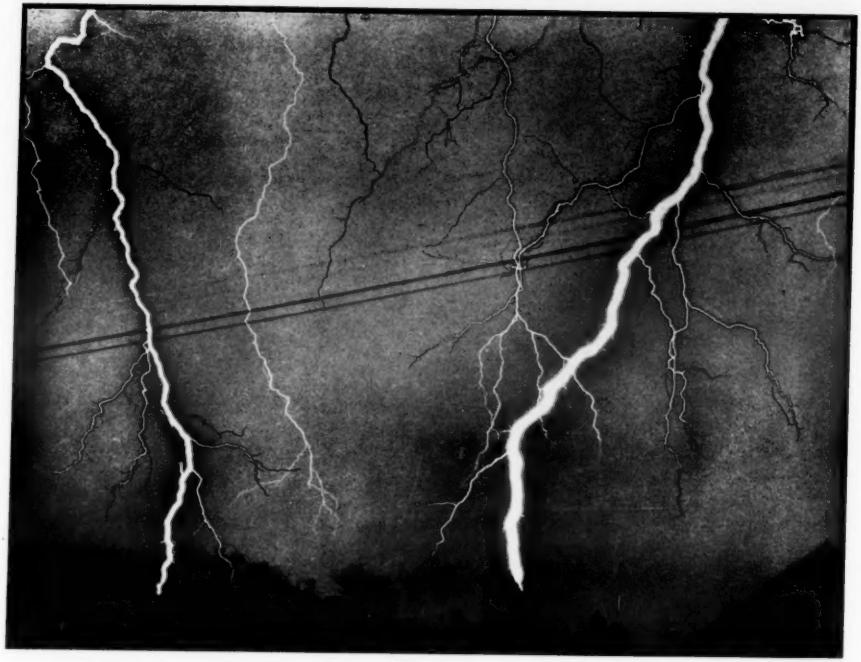


FIG. 3

PHOTOGRAPH SHOWING "DARK LIGHTNING"

Taken by Ferdinand Ellerman on Mount Wilson, California.

POPULAR ASTRONOMY, No. 283.

PLATE XI

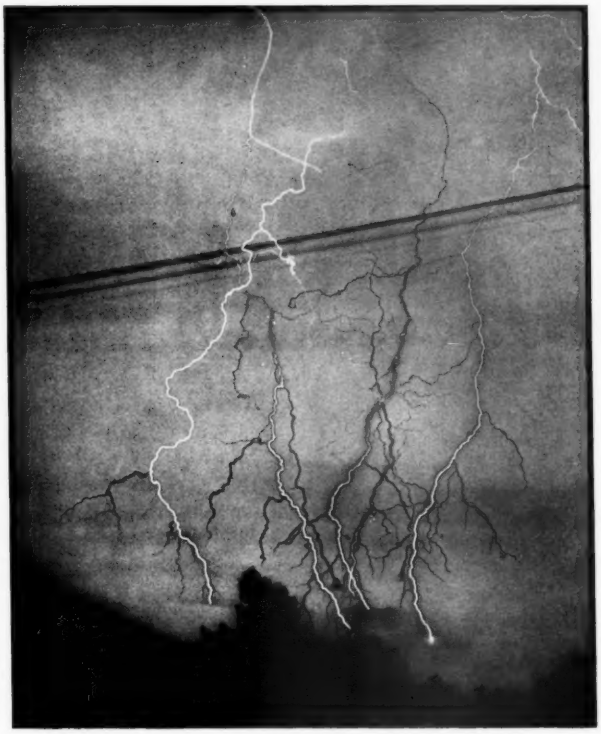


FIG. 4

PHOTOGRAPH SHOWING "DARK LIGHTNING"

Taken by Ferdinand Ellerman on Mount Wilson, California.

POPULAR ASTRONOMY, No. 283.

faint lines are all clear, and if a print is made from this negative, it shows dark, with some bright lines having dark edges.

If the image of a non-condensed spark is photographed, and the plate fogged as before, we get a reversal, more or less complete, according as to how strong the spark image is, as compared to the fogging exposure, and a print from such a negative has the appearance of the flashes of lightning shown in Fig. 4.

Single flashes of "dark lightning" could easily be explained in this way: That they were the first exposures on the plate, and the background, subsequently illuminated by later flashes, and the plate thereby fogged, causing a reversal of the first image; but when all the images of the flashes which cause the fogging of the plate, are also photographed, and all their branches, as well as some of the main trunks are reversed, this theory breaks down.

The writer has not had the time to carry out laboratory experiments in sufficient amount to throw any new light on the subject, and such phenomena as shown in Fig. 4. He has, therefore, thought it advisable to republish the photograms with the hope that someone will be interested in the subject, and carry out a series of experiments, not only in the laboratory, but on lightning itself, by using a battery of cameras, and changing the plate after every flash in one camera, while allowing more flashes to impress themselves on plates in companion cameras. Films are very convenient for rapid changing, and one operator could handle three or four cameras.

The writer will be very glad to communicate with any one desiring to investigate the subject, and will do all he can to co-operate.

Mount Wilson Observatory, January 1921.

## TWENTY-FIFTH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY.

### ABSTRACTS OF PAPERS

*(Continued from page 110.)*

#### EVIDENCE REGARDING THE GIANT AND DWARF DIVISION OF STARS AFFORDED BY RECENT MOUNT WILSON PARALLAXES.

By Walter S. Adams and Alfred H. Joy.

A discussion of the results obtained from the large number of stars with absolute magnitudes and parallaxes determined at Mount Wilson by the spectroscopic method furnishes some interesting evidence regarding the separation of stars into the giant and dwarf divisions in the various spectral types. A total of 1643 stars is available. Although

this list contains a large number of stars selected on the basis of having either very large or very small proper motions it also contains many hundreds of stars selected at random or on the basis of apparent magnitude. Accordingly, although these stars cannot be regarded as strictly representative of stars in general they approach this condition much more nearly than did the previous list of 500 stars for which absolute magnitudes were published in 1917. The evidence they afford, therefore, is entitled to higher weight, not only because of their larger number but also because the effect of selection should influence the results much less seriously.

The stars have been divided according to their spectral types, and within these types the numbers of stars of definite absolute magnitude have been determined. The limit selected is 0.5 magnitude, this narrow range being used in order to show the change of number with absolute magnitude as clearly as possible. The following table contains the results. The Cepheids and stars of similar spectrum form the great majority of the very bright stars of types F and G.

NUMBER OF STARS OF VARIOUS ABSOLUTE MAGNITUDES.

| Abs. Mag. | A | F0-F9 | G0-G9 | K0-K3 | K4-K9 | M |
|---|---|---|---|---|---|---|
| —3.0 | | | 9 | 1 | | 1 |
| —3.0 to —2.6 | | 3 | 9 | 2 | | 1 |
| —2.5 —2.1 | | 3 | 3 | | | 1 |
| —2.0 —1.6 | | 5 | 8 | | | |
| —1.5 —1.1 | | 8 | 11 | | | 2 |
| —1.0 —0.6 | | 6 | 20 | 1 | | 9 |
| —0.5 —0.1 | 1 | 5 | 34 | 9 | 1 | 20 |
| 0.0 +0.4 | 2 | 5 | 50 | 35 | 38 | 55 |
| 0.5 0.9 | 2 | 11 | 60 | 90 | 88 | 30 |
| 1.0 1.4 | 8 | 10 | 38 | 71 | 8 | 7 |
| 1.5 1.9 | 20 | 21 | 30 | 36 | | 1 |
| 2.0 2.4 | 9 | 35 | 14 | 26 | | |
| 2.5 2.9 | 3 | 46 | 12 | 7 | | |
| 3.0 3.4 | | 61 | 9 | 7 | | |
| 3.5 3.9 | | 93 | 12 | 3 | | |
| 4.0 4.4 | | 40 | 32 | 5 | | |
| 4.5 4.9 | | 5 | 45 | 5 | | |
| 5.0 5.4 | | 1 | 50 | 2 | | |
| 5.5 5.9 | | 2 | 50 | 21 | | |
| 6.0 6.4 | | | 11 | 46 | 4 | |
| 6.5 6.9 | | | | 11 | 19 | |
| 7.0 7.4 | | | | 1 | 19 | |
| 7.5 7.9 | | | | | 4 | |
| 8.0 8.5 | | | | | 11 | |
| 8.5 8.9 | | | | | 8 | 2 |
| 9.0 9.4 | | | | | 3 | 2 |
| 9.5 9.9 | | | | | 1 | 5 |
| 10.0 10.4 | | | | | | 6 |
| 10.5 10.9 | | | | | | 6 |
| | 45 | 360 | 507 | 379 | 204 | 148 |

An inspection of these results shows how extraordinarily well-marked is the division into giant and dwarf stars among those of advanced type of spectrum. No star of absolute magnitude intermediate between 1.5 and 6.0 is found among the stars of types K4 — K9, and no

star between 2.0 and 8.5 among those of the M type. The two maxima of frequency are very prominent among the stars of types G0 — G9 and K0 — K3. The most frequent magnitudes for the former are about +0.7 and +5.5, and for the latter +0.7 and +6.2. The F type stars show no evidence of two maxima unless the Cepheid variables may be considered as forming a part of this class, which is doubtful. A very large proportion of the F stars falls around absolute magnitude +3 to +4 with a rapid decrease in number beyond 4.5. The A type stars, which are few in number and are entitled to low weight on this account, show a maximum of frequency between +1 and +2.

The results obtained from this list of 1643 stars are in excellent agreement with those derived from the list of 500 published a few years ago. The effect of selection, therefore, which should have been marked in the case of the smaller list, apparently does not influence the results seriously. It is of interest to note that about 70 per cent of all the M type stars listed in the Catalogue of Boss are included in this discussion and that no single case of absolute magnitude intermediate between +2 and +8.5 has been found.

The frequencies given here are, of course, apparent frequencies and are not those reduced to equal volumes of space. A determination of the latter would involve the use of a luminosity law of which we have as yet insufficient knowledge.

## NOTE ON THE COMPARISON OF SPECTRAL TYPES DETERMINED AT HARVARD AND MOUNT WILSON.

By Walter S. Adams and Alfred H. Joy.

The completion of a list of 1643 stars for which parallaxes have been determined by the spectroscopic method at Mount Wilson makes it possible to institute a comparison of the spectral types of a large number of stars with those given in the *Revised Draper Catalogue*. Very few of these stars are of types earlier than F0, and the comparison, accordingly, has been limited to the classes F, G, K, and M. The results for the *Revised Draper Catalogue* are now available as far as 12 hours of right ascension. Within this limit there are 715 stars common to the two lists. The spectral type, the number of stars, and the mean difference of type in the sense, Harvard *minus* Mount Wilson, is given in the adjoining table. The unit is one division, or one-tenth of a spectral class.

| | Number | Difference |
|---|---|---|
| F0 — F9 | 141 | —0.02 |
| G0 — G9 | 206 | —1.37 |
| K0 — K9 | 310 | —0.77 |
| M | 58 | +0.12 |

It will be noted that the Mount Wilson determinations give a slightly more advanced type in the case of the G and K stars, while the differ-

ence is negligible for those of types F and M. It was at first thought that the difference in the case of the G and K type stars might be due to the fact that the Harvard observers use only the spectral divisions G0, G5, K0, K2, and K5, while the Mount Wilson spectra are classified to each tenth of a division. A comparison was made in which the Mount Wilson spectral classification was reduced to the Harvard basis by rounding off the values. That is, G2 would be called G0, G3 and G7 would be called G5, etc. The result showed that the difference was almost identically the same when the values were treated in this way.

An interesting result is given by a division of the G and K stars according to absolute magnitude. If we take those of absolute magnitude brighter and fainter than 5.0, we obtain the following result:

| | | Number | Difference |
|---|---|---|---|
| G0—G9 | Giants $<$ 5.0 | 152 | —0.67 |
| | Dwarfs $=$ $>$ 5.0 | 54 | —3.33 |
| K0—K9 | Giants $<$ 5.0 | 255 | —0.47 |
| | Dwarfs $=$ $>$ 5.0 | 55 | —2.15 |

The difference, accordingly, is much larger for the dwarf stars than for the giants. A possible explanation of this result is suggested by the well-known difference in the distribution of light in the continuous spectrum of giant and dwarf stars, the latter being stronger in violet light than the giants of the same spectral type. A very large proportion of the dwarf stars in this list are of faint apparent magnitude. Accordingly their spectra would be faint upon the objective prism photographs taken by the Harvard observers. If any considerable use, therefore, is made of the distribution of light in the continuous spectrum as a basis for classification the tendency would be to estimate the dwarf stars as of somewhat earlier type than giant stars of the same class. The fact that the largest difference is found for the G type stars for which the absolute magnitude effect is most pronounced is in agreement with this hypothesis.

## ADDITIONAL EVIDENCE ON CHANGES OF WAVE-LENGTH WHICH ARE PROGRESSIVE WITH STELLAR TYPE.

By Sebastian Albrecht.

That some lines in the spectra of stars vary progressively in wave-length as we pass from the so-called early to the late types was announced fourteen years ago. Similar variations were found for the same lines in the spectra of individual stars, the Cepheid variables, indicating periodic changes of spectral type in these stars which synchronize with the changes of light and of radial velocity. In his vice-presidential address at the Cleveland meeting Professor Frost made the statement that in view of these variations in wave-length it

would be necessary in the future "to study each star line by line, and each important line in its changes with spectral type." In spite of this admonition only one other observer, Joseph Lunt, has attempted to verify my observations. Although his measures deviate considerably from mine, nevertheless on the whole they show variations similar to mine.

My results were based almost entirely on my own measures. In order to eliminate the slight outstanding possibility that my variation might rest largely upon personal factors, it seemed desirable to test measures of other observers. Such measures are available in the detailed radial velocities given in Volume IX of the *Publications of the Lick Observatory*. Accordingly I have computed the wave-lengths for all the measures by Palmer and by Wright which are given in that volume. Without going into details, I may summarize in the general statement that for each of these observers my "variable lines" show changes in wave-length as we pass from the A to the M types which are similar to those which I had obtained from my own measures. Amidst the general agreement certain outstanding differences appear, which are in part due to the effect described below.

Comparatively recently Hertzsprung and Russell have shown that it is possible to group the stars according to size into the two classes of "giants" and "dwarfs." It seemed probable, and especially so on the basis of recent work by Adams and other Mount Wilson observers, that it would no longer be sufficient to determine the changes of wave-length with reference to changes of spectral type alone, but that the wave-lengths may vary differently, through the same series of types, in the giants from in the dwarfs. This distinction introduces quite a considerable, though fortunately only temporary, difficulty, due principally to the fact that the great bulk of my data is for stars in the southern skies. Parallaxes are available for only 11 out of a total of 115 southern stars employed in the tests outlined above. Fortunately the proper motions are moderately well determined for all of these stars. Recourse was therefore had, as a temporary makeshift, to the assumption that in the mean a large proper motion indicates a large parallax and a small proper motion a small parallax. And, as the visual magnitudes are approximately the same in the two divisions, that therefore also the large proper motion indicates a small absolute magnitude, i. e., a dwarf star, and similarly a small proper motion corresponds to a giant star. This, of course, may be wide of the mark in individual cases, but it expresses the facts approximately in the means of considerable numbers of stars, and for the present is the best that can be done. When the stars were separated into classes according to the size of the proper motion, it was found that the wave-lengths for the variable lines varied differently in the large from in the small proper motion group.

In addition to confirming in a general way my former results on

variation of wave-length with type, the above tests show: (a) that my former results need revision on the basis of distinctions other than that of type, especially, perhaps, on that of luminosity, and, (b) that there is urgent need for enthusiastic parallax observers in the southern hemisphere, to determine and accumulate a large list of parallaxes for southern stars.

## A HARMONIZING OF ALL ANNOUNCED SUN-SPOT PERIODICITIES.

By Dinsmore Alter.

Attention was called to the fact that statistical evidence alone can never entirely settle negatively the question of constant periodicities in sun-spot intensities. All that statistical data can do is to make such periodicities seem more or less probable. The final question must be settled from a knowledge of the cause of sun-spots unless in future years the comparatively irregular sun-spot sequence should be found to repeat itself more or less perfectly in a very long period.

The main part of the paper was devoted to the discussion of two tables. In the first of these tables are shown all announced periodicities less than fifty years with the exception of Kimura's which were treated separately. Each of these periodicities is seen to fall very closely as a harmonic of 66.75 years. Since approximately fifty years elapsed between the earliest and the latest of these investigations and since, therefore, the data used must be quite different, the objection made by Turner in his discussion of Kimura's paper cannot apply with full force against these harmonics. The second table discussed all announced periodicities of length greater than fifty years and showed that they are quite closely harmonics of five times the sixty-six year period discussed above.

An analysis of all sun-spot data discloses indication of a period of about sixty-six years with an amplitude three-fifths that of the eleven year period.

The conclusion is that although the periodicities are not as certain as has been stated by certain advocates, nevertheless, the arguments against them have also been over-stated and the question of constant periodicities is still an open one.

## THE ASSOCIATION OF HYDROGEN LINES WITH THE "INVARIABLE" K LINE IN THE SPECTRUM OF $\kappa$ DRACONIS.

By Robert H. Baker.

This star has been under observation at Ann Arbor since 1912 in connection with Professor Curtiss' program of Class B spectra containing emission lines. The spectrum resembles that of $\gamma$ Cassiopeiae.

The hydrogen series consists of broad emission lines centrally superposed on broader absorption, while narrow absorption lines appear nearly central upon the emission. Broad absorption lines of helium and other elements are present. The K line is narrow. Representatives of the broad absorption and emission lines are found to oscillate in a period of 8.986 days with a velocity range of 31 km per second.

The narrow hydrogen lines do not share the short period variation, but they change position gradually. If their variation is periodic, the Ann Arbor velocities suggest a period of 4 years and a velocity range of 12 km per second. The broad lines have no part in the gradual displacement. The narrow H$\beta$, which is frequently measured on the early plates, diminishes in width and intensity during the interval 1912-15 and thereafter is not seen. No corresponding change is observed in the H$\gamma$ line.

The K line certainly accompanies the narrow hydrogen lines in the gradual variation and it gives no evidence of participation in the short period oscillation of the broad lines. In the spectrum of $\kappa$ Draconis we have therefore another example of the anomalous K line which was observed first in the spectrum of $\delta$ Orionis and later in other stars; and in this case the hydrogen lines are associated with the K line.

According to current views, the peculiar K line is produced by absorption within a medium either lying between us and the binary or else enveloping that system. The feeble absorption of the medium becomes noticeable, of course, only in the event of weak absorption within the star itself by the elements which compose the medium, or in case the effacing star lines are sufficiently displaced by the revolution of the star. This consideration may explain the preference of the peculiar K line for stars of types preceding the strong development of this line, and the failure so far to find hydrogen lines associated with the calcium.

The broad emission of $\kappa$ Draconis offers a favorable background for the hydrogen lines of the supposed medium. But the cloud theory fails in this case, unless we can account for the gradual shifting of the narrow lines. An alternative view is that $\kappa$ Draconis is a triple star, consisting of a short period binary whose brighter component is of Class B5p and a distant, less massive companion of Class A having a period of several years. This view will be strengthened, if further observations establish the periodicity of the gradual variation. But the disappearance of the narrow H$\beta$ will require explanation.

## OBSERVATIONS OF THE PRESENT DISAPPEARANCE OF THE RINGS OF SATURN.

By E. E. Barnard.

The phenomena of Saturn's ring system from 1920 November 7 to 1921 August 3 are of exceptional interest, because we are able to study

the physical appearance of the ring from its unilluminated or dark side. The observations of 1907-8, when the rings were similarly situated, showed that they were visible when the sun shone only on the side turned away from us, which was unexpected. There appeared upon the rings at that time what seemed to be luminous "condensations" with appreciable thickness. It was shown in the observations of that season that these appearances were not due to actual condensations or thick places on the rings, for they were entirely invisible near and at the time when the ring was edge on to us. This proved that they were really the obscure surface of the ring illuminated by sunlight sifting through or among the individual particles composing the rings, and thus making them more or less feebly visible.

The critical phenomena presented by the rings at the present disappearance are much like those of 1907-8 and are extremely favorable for observation, especially with powerful telescopes.

The following statement will make clear the conditions under which the rings disappear and reappear during the present opposition of the planet.

The sun shines on the south side of the ring until 1921 April 10, when it passes to the north side. The earth was on the south side of the ring until November 7, 1920, when it passed to the north or dark side, where it remains until February 22, when it passes to the south or bright side. On April 10, as stated, the sun passes to the north side and leaves the earth on the dark side again, where it remains until August 3, when it passes to the north or sunlit side of the ring. Part of this program has been carried out and is of the deepest interest.

Up to November 4 (near the time when the ring plane passed through the earth, on November 7) the ring appeared, with the 12-inch telescope, as a gradually thinning bar of light with no roughness or inequalities upon it. The 5th and 6th of November were cloudy, but the 7th was clear and at $22^h$ G.M.T. satisfactory observations of the planet were made with the 40-inch telescope. No trace of the ring or condensations could be seen, even when Saturn was hidden. No other observations were had with the large telescope until November 13 at $22^h$, when the rings were feebly seen, but the condensations were not visible. On November 27, however, at $22^h$, the ring and condensations were well seen, and appeared exactly as they did in 1907. Measures of the condensations agreed very closely with those made in 1907. The ring and condensations (as in 1907) were very much less bright than the ball of Saturn.

The results of these observations confirm those of 1907 and show how incredibly thin the rings must be. Observations[1] of a thin wire with the naked eye show that such can be seen when projected against a daylit sky when the angular width is only 0″.43. If this were a luminous wire seen against a black background, the angular width that

[1] Popular Astronomy, **5**, 2, 1897.

could be seen with the naked eye would be very much less. Substitute now for the luminous wire the sunlit edge of Saturn's ring, and for the naked eye the 40-inch telescope, and we can imagine how small an angular width the ring must have to escape notice. One would not like to venture a guess what this angular width may be, but it probably would be less than 0".01 or less than thirty miles in thickness. Russell's[2] estimate of their thickness, about 21 kilometers, therefore, seems reasonable.

## PROBABLE EXPLANATION OF THE APPARENT ELONGATION OF THE GEGENSCHEIN.

By E. E. Barnard.

The Gegenschein was carefully observed the past fall (when conditions permitted) for the change of form that takes place in it in the first part of October. From these observations I am convinced that the apparent change in form is due to its projection on to a zodiacal band in this part of the sky. There seems to be a permanent part of a zodiacal band that extends along the ecliptic from between the Pleiades and Hyades to just south of the eastern part of the square of Pegasus or in about right ascension $0^h$. It does not seem to continue west of this until the zodiacal light reaches that point. Apparently the change to an elongated form occurs every year, when the Gegenschein is projected on this band, and is not real, but is due to the mingling of its light with that of the band. Just before this apparent change takes place, the Gegenschein is at its largest and brightest, when it appears as a very large roundish diffused mass of noticeable light, sometimes 40° or 50° or even more in diameter and seldom less than 30°. It is distinctly visible when looked at direct, and rather conspicuously so when seen by oblique vision. At no other point in its path is it so large. This should be taken into account in any investigation of its true nature. Immediately after this it becomes smaller and apparently elongated through projection on to the zodiacal band.

## COMMENTS ON THE SPECTRUM OF NOVA CYGNI NO. 3 AND NOVA AQUILAE NO. 3.

By S. B. Barrett and Edwin B. Frost.

For exhibition at the summer meeting at Northampton in 1920, slides were hurriedly made up covering the first seven days of observa-

[2] *Astrophysical Journal*, **27**, 233, 1908. Louis Bell inferred a thickness of 15 km for the rings (*Astrophysical Journal*, **50**, 10, 1919).
For the writer's observations in 1907 see *Monthly Notices*, **68**, 346-366, 1908; **69**, 621-624, 1908. *Astrophysical Journal*, **27**, 35-44 and 234-235, 1908.

tion here on the spectrum of Nova Cygni, viz., from Aug. 23 to 29. The slides did not do justice to the excellence of the original spectrograms. Accordingly for this meeting at great pains Mr. Barrett vertically enlarged those spectrograms which we regarded as the most important, and combined them on three slides which fairly cover the spectroscopic history of Nova Cygni from Aug. 23 to Sept. 17. The comparison lines from the spark of titanium and iron are imprinted with each spectrogram. The dates included are 1920, G.M.T. Aug. 23.58, 23.87, 24.56, 25.58, 26.62, 26.75, 27.59, 28.69, 29.54, 29.56, 30.57, 30.90, 31.57; Sept. 1.69, 2.56, 3.59, 3.65, 6.83, 10.57, 13.70, 17.76.

Similarly for Nova Aquilae, enlargements were made on the same scale, from which three slides were prepared covering the following selected dates (7 spectra on a slide): 1918, June 10.68, 11.61, 12.64, 14.64, 14.82, 28.73; July 1.68, 5.71, 8.80, 12.90, 26.66, 29.65; Aug. 5.65, 12.64, 26.59; Sept. 6.55, 13.55, 27.56, 30.58; Oct. 28.54; Nov. 11.50.

Attention was called briefly to the more conspicuous changes shown on these spectra, all of which were made with the Bruce spectrograph, arranged for one prism and attached to the 40-inch telescope.

## THE SYSTEMS OF MAGNETIC FORCES DURING THE SOLAR ECLIPSE OF MAY 29, 1919.

By Louis A. Bauer.

With the aid of the magnetic data observed by the various expeditions of the Department of Terrestrial Magnetism during the solar eclipse of May 29, 1919, and by co-operating observatories, an analysis was made of the systems of forces which produced the observed magnetic effects.

The vectors showing the combined effect in declination and horizontal intensity invariably were found to point approximately towards a focus located in the vicinity of the shadow cone and moving with it over the earth as the eclipse progressed from station to station.

With the aid of the vertical-intensity effects, it was found that the eclipse magnetic systems were composed of an external and an internal system of forces. The analysis in general shows that the eclipse magnetic systems of May 29, 1919, have characteristics analogous to those exhibited by the systems causing the solar diurnal and the lunar diurnal variations of the earth's magnetism.

It was furthermore found that the observed magnetic effects could not wholly be referred to a potential; there was an appreciable outstanding portion which clearly showed the existence of vertical electric currents passing through the surface of the earth in the region of visibility of the eclipse. The line integrals of the magnetic force were computed for circuits of various dimensions, inclosing Sobral, Brazil, where atmospheric-electric observations were made by the expedition

of the Department of Terrestrial Magnetism. The slides shown exhibit the results of these computations. There was a drop during totality of the eclipse in the vertical electric current resulting from the magnetic observations, corresponding with the drop in the vertical current shown by the atmospheric-electric observations. The strength of the vertical current resulting from the magnetic observations was about 3,000 times that from the atmospheric-electric measurements.

## THE LIGHT-CURVE OF NOVA CYGNI NO. 3.

By Leon Campbell.

The light-curve of this bright Nova is in several respects different from those of other recently discovered novae. Found by Denning on August 20 at about the third magnitude, it gradually increased to a maximum of 1.9 on August 24. A photograph taken at Harvard on August 19 showed the star at magnitude 4.8—photographic scale—and one at Upsala on the 16th showed it at magnitude 7. This would indicate a slower rise to maximum than is usual in many novae, and if a smooth curve is drawn through the observations obtained from August 16 to August 24, all but those on the day of discovery fall on a straight line. Extending this curve backwards to the magnitude 16, which is the limit at which the Nova must have risen from, according to published information, it would appear that the star began to rise on or about August 4.

Fortunately, there are no fictitious reports of this Nova having been seen at varying degrees of brightness before the date of discovery by Denning, so that the early history of the star is not clouded in mystery as was the case in the last bright nova.

The decrease from maximum was somewhat rapid and uniform, at least until early in October. In fact at one time it looked as though the star would soon drop to its faint stage and quickly lose its interest from a visual point of view. As far as the observations show, there has been little, if any, indication of fluctuations, so noticeable in some of the other bright novae.

At about Julian Day 2422600 a marked decrease was observed, but within a few days the star resumed a more gradual rate of decrease and at the present time it is hovering around the magnitude 9.

Over 1,300 observations have already come to hand and there is not a night up to the first of December that the Nova was not under observation by at least one observer since its discovery.

The first slide showed the mean light-curve derived from 1,328 observations. Many of the seeming irregularities near the end of the curve will doubtless disappear when more observations are received from the score or more of observers.

The second slide gave an idea as to how three other novae acted

during their early stages of visibility. It was noted that Nova Persei No. 2 still holds the banner for greatest interest from the point of view of the visual observer.

## SOME NEW METHODS FOR DOUBLE STAR ORBITS.

By George C. Comstock.

This paper deals with two methods, supposed to be new, that are frequently useful in the determination of double star orbits, viz:

A. To draw the apparent orbit use may be made of the geometrical principle that for any ellipse the locus of the intersection of tangents that meet orthogonally is a circle whose center is at the center of the ellipse and the square of whose radius is equal to the sum of the squares of the semi-axes of the ellipse. The observed position angles and distances should be separately plotted as ordinates with the time as abscissae and the resulting curves adjusted to satisfy the law of constant areal velocities. From these curves adjusted values of the co-ordinates at convenient time intervals may be read, plotted, and a smooth curve drawn through them as a first approximation to the apparent orbit. From this curve by means of a straight edge and draughtsman's triangle locate a series of points representing the intersections of mutually perpendicular tangents to this curve and by trial with dividers find the circle that best fits this set of points. Its relation to the apparent orbit as set forth above, furnishes an adjusted orbit every part of which depends upon all of the data employed.

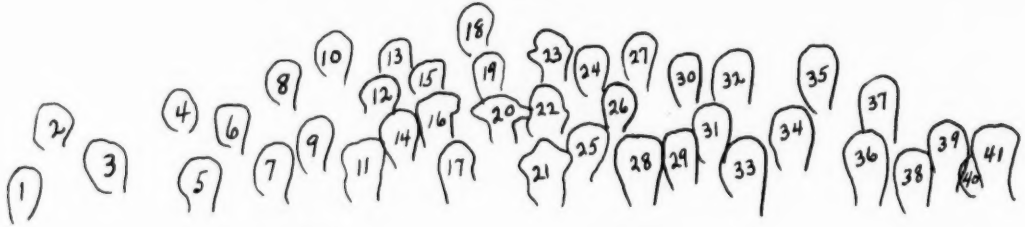
B. To pass from the apparent to the true orbit: Draw that diameter $b$ of the apparent orbit which is conjugate to the diameter $a$ passing through the principle star, and produce $b$ in the ratio $1 : \sqrt{(1-e^2)}$. Take any diameter of the ellipse as an axis of $x$ and with respect to it measure the co-ordinates $x, y, x', y'$ of those extremities of $a$ and $b$, produced, that lie upon the same side of the axis. If the diameter thus chosen happens to be the line of nodes these co-ordinates will satisfy the relation $xy + x'y' = 0$, and in general they will not satisfy this relation for any other diameter. The diameter that satisfies this relation may easily be found by trial. Thus, if a straight edge be made to pass through the center of the ellipse and two triangles be so placed in contact with it that their edges passing through the extremities of $a$ and $b$ render visible the co-ordinates $x, y, x', y'$ the condition above noted among these quantities will be satisfied when the triangle whose sides are $x\ y\ a$ and $x'\ y'\ b$ have equal areas, since this is the geometrical equivalent of the algebraic relation in question. The position thus found should be regarded only as a first approximation and a definitive position of the line of nodes should be based upon carefully measured values of the co-ordinates.

The elements of the true orbit $a, i, \omega$ are related to these co-ordinates

PLATE XII

GROUP AT THE CHICAGO MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY, DECEMBER, 1920.

KEY TO PLATE



1. Van Biesbroeck
2. Alter
3. Fath
4. Miss Jessica M. Young
5. Swezey
6. Chant
7. Moulton
8. Rufus
9. Mees
10. Barnard
11. Leuschner
12. Miss Hamlin
13. Roberts
14. Ross
16. Stebbins
17. MacMillan
18. Morehouse
19. H. H. Plaskett
21. Michelson
22. Rigge
23. Barrett
24. Joy
25. Albrecht
26. Mrs. Joy
27. Miss Hill
28. Silberstein
29. Frost
30. Miss Anne S. Young
31. R. H. Curtiss
32. Humphreys
33. D. T. Wilson
34. Baker
35. Lee
36. Stewart
37. Manson
38. Bauer
41. Slocum

through the following relations which suffice for their determination:

$$a \sin \omega = -x' \qquad a \sin \omega \cos i = y$$
$$a \cos \omega = +x \qquad a \cos \omega \cos i = y'$$

The condition above imposed, $xy + x'y' = 0$, does not uniquely determine the line of nodes since if it is satisfied by any diameter of the ellipse it will also be satisfied by a line at right angles to that diameter. We may discriminate between these two possible positions of the nodes through the relations

$$x^2 + x'^2 = a^2 \qquad y^2 + y'^2 = a^2 \cos^2 i$$

If $x^2 + x'^2 > y^2 + y'^2$ the diameter originally chosen is the line of nodes and *vice versa.*

The remaining elements of the orbit, periodic time and periastron passage, are best determined from the plotted curve of position angles.

## AN INSTRUMENTAL SOURCE OF DOUBLING OF EMISSION LINES IN γ CASSIOPEIAE.

By R. H. Curtiss.

The paper was designed to emphasize the fact that strong well defined emission lines in stellar spectra become double when produced by an objective prism combined with a Newtonian or Cassegrainian reflector, if the photographic plate is sufficiently out of focus and if the spectrum is widened in the usual ways either by allowing the image to trail or by using a cylindrical lens. The same is true of such lines when produced by a slitless focal plane spectrograph attached to reflectors of the types mentioned.

With these instruments the image of a bright line like Hα or Hβ in γ Cassiopeiae's spectrum is a small ring when out of focus, like the corresponding extra focal star image. When such an image trails along the plate or is drawn out by a cylindrical lens in the process of widening the spectrum a double line is generated. Such spurious doubling can usually be detected, if there is any question about its source, by the facts that (1) the separation of the components of the doubles will be essentially the same in all regions of the spectrum, (2) the spectra corresponding to one position of the star image, which usually appear in stellar spectrograms made with slitless instruments, are wide or double, (3) the components of the doubled lines may exhibit differences of intensity due to different degrees of absorption near the base and near the refracting edge of the prism. A trial plate with the star image in one position or with cylindrical lens removed would reveal focal maladjustment and would avoid danger of error from this source.

Artificially doubled bright lines were shown in spectra of γ Cassiopeiae, made with slitless spectrographs combined with Newtonian and Cassegrainian reflectors.

## THE SEARCH FOR THE GRAVITATIONAL EFFECT PREDICTED BY EINSTEIN FOR SOLAR WAVE-LENGTHS.

By Ralph E. DeLury.

On account of the differences obtained by different observers for the comparisons between terrestrial and solar wave-lengths, as well as the unexplained differences for different substances and for lines of the same substance, the presence of the Einstein effect for solar wave-lengths is still in doubt. The method, employed at Ottawa, of photographing simultaneously nine strips of spectra including at least two strips each of spectra of centre, midway and limb points on the sun with two strips of arc spectra, possesses advantages in the investigation of this problem. Measurements so far made show for the cyanogen band in the ultra-violet, the magnesium triplet in the green and two iron lines near them, the following differences from the arc, (fine emission lines of magnesium were obtained from magnesium oxide fused with an iron oxide bead employed in an arc of the Pfund form, 12 mm long of 6 amperes),—

| | Centre-Arc | Midway-Arc | Limbs-Arc |
|---|---|---|---|
| 33 cyanogen lines | 0.314 km/sec. | 0.264 km/sec. | 0.224 km/sec. |
| 3 magnesium lines | 0.081 | 0.154 | 0.062 |
| 2 iron lines | 0.694 | 0.660 | 1.334 |

The differences for the cyanogen lines are larger than those obtained by St. John, and agree better with those of Evershed. The values for the magnesium lines support the conclusions for these lines deduced by St. John, while those for the iron lines resemble those obtained by Evershed for similar lines. I am inclined to attach more importance to the negative evidence of the cyanogen and magnesium lines than to the positive evidence (resembling the value 0.634 km/sec. predicted by Einstein) of the iron lines, for iron lines exhibit a great range in behaviour pointing to physical variations in the sun. (Can this be in part due to the fact that iron is an important constituent of some meteors and that a component of their falling motion into the sun is exhibited in the displacements of these lines?) Before the complications in this problem are finally removed a great many determinations of wave-length for many lines of various elements must be made at many points on the solar surface, a program on which we are now engaged in Ottawa.

## FURTHER NOTE ON FLUCTUATIONS IN THE MOON'S LONGITUDE IN RELATION TO METEOROLOGICAL VARIATIONS.

By Ralph E. DeLury.

At an earlier meeting the question was raised as to whether the tree-growths (measurements of which were given in Huntington's *The*

*Climatic Factor*) exhibited periods corresponding to the 260 and 60 (or 70) year periods in the fluctuations of the moon's longitude. For a total of 12 cycles (of 260 years) there appeared to be some evidence in support of the long period, while a single cycle in which the 60 or 70 year ripples showed markedly gave only fair support to an incomplete cycle of rainfall (Upsala) which seemed to fit the long period; while the short period (which Brown had shown agreed in phase with the 60 or 70 year cycle in sun-spots) was found to agree very well with a similar period in the tree-growth as well as in the rainfall. The tree-growth showed the 60 year period for 6 cycles, a result which is well shown in the analysis by Douglass of the same material (*Climatic Cycles and Tree-Growth*, p. 109), where a period of about 65 years appears, so that the short period seems well substantiated in the tree-growths, the lunar and the solar data. The long period does not seem to be periodic in the same sense, (Turner has recently found no evidence of the long period in the tree-measurements of Douglass), though for the one cycle there is meteorological evidence in the same phase, and this latter is supported further back than the Upsala record goes by the records of floods of the Seine (Flammarion, *L'Astronomie*, 1910, p. 136, and Henry, *Monthly Weather Review*, 1919, p. 865), which show exceptional inundations in 1649, 1651, and 1658, and again in 1910 (and 1920?), with lower floods in between these extremes. The intermediate floods group themselves (as Henry pointed out) and these groups fit fairly well in phase with maxima of the short period.

## SECOND NOTE ON THE DISPLACEMENTS AND WIDENING OF SPECTRUM LINES AT THE LIMB OF THE SUN.

By Ralph E. DeLury.

The excess of the far component over the near component in the penumbral displacements of spots is supposed to have an analogue in pores, but the pore being smaller both components in general would enter the slit of the spectroscope and produce a widening of the lines in passing out to the limb. Measurements of the change in width of lines at midway and limb points compared to widths of the spectrum lines from the centre of the disc show the following for 24 lines at λ5200,—

| Number of Lines | Average Intensity | Excess of Width Over Lines from Centre | |
|---|---|---|---|
| | | Midway | Limb |
| 3 | 1 | —0.02 km/sec. | 0.37 km/sec. |
| 6 | 2 | 0.11 | 0.56 |
| 5 | 2 (enh.) | 0.21 | 0.61 |
| 7 | 5.3 | —0.25 | —0.13 |
| 3 | 22 | 0.06 | 1.17 |

These differences are within the range of possibilities of widening resulting from convections of the order of those in sunspots, and a

preponderance of the receding component would in part perhaps account for the increase in wave-lengths at the limb which is generally observed, but other factors (such as Doppler widening of the lines in the centre spectra) undoubtedly enter into the above differences in width, as, undoubtedly other factors must enter into the differences in wave-length. It is advisable, however, to regard the pore effect as a possibility in the present chaotic state of the interpretation of solar wave-lengths and their variations.

## SOME MEASUREMENTS OF THE DISPLACEMENTS OF SPECTRUM LINES IN THE PENUMBRAE OF SUN-SPOTS.

By Ralph E. DeLury and John L. O'Connor.

A series of spectra of sun-spots were photographed from March 31 to September 22, 1914, with the slit of the spectroscope crossing the spot in line with the centre of the solar disc, to record the displacements of the lines in the penumbrae (Evershed effect), in all 750 observations being made. Some of these plates have been measured in connection with other problems, particularly in determining relative levels for lines used in measurements of the solar rotation, and on this account the regions λ4250 and λ5600 were well observed. The observations include spectra of the advancing and the following members of pairs of spots; and on one date (June 18) two spots (or rather two nuclei in a large penumbra) were observed together when the line joining them passed through the centre of the solar disc, the nuclei being 46 and 48 mm from the limb, and the diameter of the disc 227 mm. It was at once apparent that in the 6000 km strip of penumbra lying between the nuclei the displacements were considerably less than in the outside parts of the penumbra, and a measure of 15 lines (intensities 1—5, λ4250) yielded 0.05 and 0.59 km/sec. respectively. However, the clearer case of two more separated spots—believed to be physically connected as though they were opposite ends of a vortex, as Hale has suggested—was examined with results supporting the idea that the axes of the two spots were inclined differently to the solar surface in such a way that the near side of the following spot yielded low displacements of the lines relatively to the near side of the advancing spot. The following measurements were made of spectra of the pair of spots in the eastern hemisphere, April 3, 38.5 and 42.5 mm from the limb, solar diameter 230 mm, A and F denoting the advancing and following spots,—

| Number of Lines | Average Intensity | Average Velocities in Penumbrae, km/sec. (Far Edges) | | | Average Velocities in Penumbrae, km/sec. (Near Edges) | | |
|---|---|---|---|---|---|---|---|
| | | A | F | A - F | A | F | A - F |
| 4 | 1.0 | 1.437 | 1.160 | 0.277 | —1.865 | —0.608 | —1.257 |
| 2 | 2.5 | .915 | .688 | .227 | — .960 | — .574 | — .386 |
| 4 | 6.8 | .298 | .263 | .035 | — .723 | — .492 | — .231 |
| 10 Means | 3.6 | .877 | .707 | .170 | —1.227 | — .555 | — .672 |

Average velocity in advancing spot, A, 1.052 km/sec.
Average velocity in following spot, F, 0.631 km/sec.

Sixty observations at λ5600 for spots, in both east and west hemispheres, whose distances from the limb varied from 6 to 60 mm, yielded an excess of velocities in the far over the near penumbrae, of 0.118 km/sec. for 3 lines of average intensity 0.3, and 0.039 km/sec. for 3 lines of average intensity 5.3. (Results in harmony with some obtained by Evershed.) These results support the hypothesis (of a pore effect similar to the spot convections) advancing as a possible factor in the widening and increase in wave-lengths of the spectrum lines in passing out to the limb of the sun.

## NOTES ON ATMOSPHERIC CONDITIONS AT TUCSON, ARIZONA, 1909-1920.

By A. E. Douglass.

A five year record on a Callendar pyrheliometer at Tucson gives 56 per cent of the days clear or nearly so, 34 per cent half clear, and less than 10 per cent wholly cloudy or nearly so. Nights are usually clearer than days. On the average then 27 nights per month have had a substantial amount of clear sky; probably 25 per month could have been used. Tests of quality of the atmosphere by Pickering's scale or by visual work on the planets requiring extremely steady conditions, have been made with the 8-inch telescope on 523 nights in the last 11 years. Of these 77 per cent, corresponding to about 20 per month, gave results of value in the planetary work; 40 per cent, corresponding to about 10 per month, were classed as fine. The majority of these tests were before midnight. A thin haze was not a disadvantage. July and August are not well represented in these tests.

## DETERMINATION OF STELLAR PARALLAXES AT DEARBORN OBSERVATORY.

By Philip Fox.

Work on the stellar parallax program of the Dearborn Observatory interrupted by the war has now been resumed. The paper gave results for twenty-three fields. For the most part the results are for faint

stars of larger proper motion. The accuracy attained in earlier determinations has been maintained through this series; the probable error, excluding one or two fields where the error is large for known reasons, such as the merging of close double stars, is about $\pm 0''.01$. The plates have for the most part been exposed at the telescope by Brown, Wylie, and Fox. Seven different persons have taken part in the measuring of the plates—Messrs. Wylie, Dixon, and Fox, and Misses Bannister, Hill, Young, and Tibbles.

## ON SOME "IRRECONCILABLES" AMONG STELLAR RADIAL VELOCITIES.

By Edwin B. Frost.

(1) Reference was made to the resumption with the Bruce spectrograph of observations of the companion to Mizar (14″ distant) of type A2 and magnitude 4.0. Nineteen plates, taken chiefly in 1916, have recently been measured by Miss Block; they yield negative values, ranging from 1 to 18 km/sec., except for one plate of Feb. 20, 1921, which gave + 9 km/sec. It has still remained impossible to discover a period. Plates taken at short intervals occasionally indicate a rapid change of velocity; it would also appear that the value of $\gamma$ changes, implying the presence of a third body.

(2) The brighter visual component of 29 $\pi$ Boötis (spectrum A0, magnitude 4.9) was also cited as an object for which it is difficult to find a period. The measures extend over many years, 52 plates having been secured. The earliest plates were measured by Frost, the later ones successively by C. A. Maney, G. S. Monk and Miss E. W. Wickham. The velocity, determined from the plates of the very best quality, ranges from + 17 to 0 km/sec. The average velocity for all the better plates is + 4.4 km, which is presumed to be the approximate velocity of the system. The variable velocity of this star has probably not been mentioned in print heretofore.

(3) The star 7 $\epsilon$ Aurigae (spectrum F5p) has been under regular surveillance here for some time. Our first plates were taken in 1899 and disclosed the spectrum to be one of exceptional beauty, suggestive of that of $\alpha$ Cygni. The star was announced as a spectroscopic binary, with composite spectrum, by H. C. Vogel in 1902, from observations by himself and Messrs. Eberhardt and Hartmann. The variation in velocity was confirmed at the Lick Observatory, and by our measures in 1901 (unpublished). Ludendorff's thorough study (*Astronomische Nachrichten*, **164**, 81, 1903) of the luminous variation of the star indicates that it is a variable of the Algol type, with period of 27.1 years; the magnitude is constant for 25.1 years; the middle of the last minimum was in March 1902. We have over 50 plates taken with the Bruce spectrograph, the larger number of them during and since 1917. They have been measured by Miss Wickham and Miss Block in succes-

sion. A range of 12 km was shown on 14 dates in 1917, with the average radial velocity of —4 km. In 1918, 4 plates gave an average value of —3 km. No negative value has been observed since April 22, 1918. A range of 13 km was obtained on 10 dates in 1920, when the average value was + 13 km. The spectrum is not now composite, but that stage may be expected to begin before long. A period of a few months seems to exist in addition to a long period.

## NOTE ON NOVA CYGNI NO. 3.

By W. E. Harper.

Our list of plates of this Nova is not as extensive as we should have desired. Cloudy weather and a crowded program in the early evening hours prevented it from being observed as frequently as would otherwise have been the case. Nevertheless, nineteen plates on twelve nights in August and September furnish data for a few notes.

The plates of August 24 showed a strong continuous spectrum with broad absorption lines of hydrogen displaced toward the violet corresponding to a velocity of 650 km/sec. approach—the equivalent of 9 angstroms at the Hγ region. Broad but fainter and more elusive absorption lines which could be identified with enhanced lines of iron and other elements were also present with displacements similar to the hydrogen lines. The H and K lines of calcium were especially strong and similarly shifted. As there seems to be some difference of opinion as to when emission first made its appearance, it may not be amiss to record that there seems no reasonable doubt of its presence on our plates of this night at G.M.T. 16½ hours. Its presence at Hγ and farther to the violet is open to question but at Hβ and at the enhanced lines at λ4924, λ5018 and λ5169 there is a decided strengthening of the continuous spectrum which is unmistakable. Fine sharp H and K lines of calcium undisplaced were also a feature of the spectra as in other recent novae. The velocity deduced for these from fifteen plates up to September 2 was —16.9 ± 0.25 km/sec., practically identical with the component of the solar motion in that direction, so that if these lines indicate the real motion of the star it is practically at rest with respect to the stellar system. Such of course was found to be the case in Nova Persei 1901, Nova Geminorum 1912, and Nova Aquilae 1918.

The development of the spectrum during the remaining days of August was marked by the formation of the usual nova emission bands, their increases relative to the continuous spectrum and by the increase in the displacement of the dark bands. From a displacement of 9 angstroms (referred to Hγ) on August 24 these increased to 12 on August 25, to 16 on August 27, and seemed to reach a maximum of a little over 17 angstroms by the end of the month.

The emission lines were strongest at the red end and rapidly became

fainter as the violet was approached. On a panchromatic plate taken on September 2 with a dispersion such that from Hα to K was 32 mm the red Hα is a very outstanding feature of the spectrum. This band is the probable cause of the strong orange color to the telescopic image during the latter half of September. The widths of the emission lines is much less than was the case in Nova Aquilae, rough approximations being as follows: Hα = 40, Hβ = 27, Hγ = 19 and Hδ = 18 angstroms. All begin to show structure as early as August 27 with two maxima at the sides and faint absorption between.

The numerous emission and absorption bands between Hα and K have been measured and will be given in detail elsewhere.

*(To be continued.)*

## THE MEASUREMENT OF AZIMUTH.

By JOHN G. KELLAR.

The writer presents herewith some tables intended to be of assistance in the measurement of azimuth, and designed to illustrate the principles that should govern observing; adding some suggestions with reference to the construction of tables in the field. He has in mind a precision of measurement attainable with an 8-inch repeating theodolite, believing this to be about as follows, when the latitude uncertainty is small:

The azimuth of the mark as determined from any one of four observations on circumpolar stars should not vary more than 1″ from the mean.

There are still a few surveyors who are content to scale their latitude from a chart and to observe on Polaris at elongation without making observations for local time. Leaving out of consideration the fact that Polaris is rather large for accurate bisection, and that the image is so unsteady that it is doubtful whether the moment of elongation can be detected with certainty by a theodolite without accompanying time observations, the placing reliance upon a single observation (with repeated angles, of course) on one star at elongation is not good practice; for it is at that time that the error arising from uncertainty in latitude enters with the greatest influence. The time error can be corrected and minimized on the spot, but the error arising from erroneous latitude cannot be corrected with ordinary field instruments. Strictly speaking, this is not an error, but an uncertainty.

Though these two sources of error (and others) are treated exhaustively on the theoretical side in textbooks, in the following partial discussion the writer hopes to add something of value from a practical

standpoint, by way of concrete illustration; and to give some idea of the possible numerical magnitude of time and latitude errors.

*Error due to error in observed local sidereal time.*

The error in time as determined in the field with the aid of a theodolite fitted with a prismatic eye-piece admitting of observing at high altitudes may be taken as about ½ second, with a sidereal hack, using the eye-and-ear method; or between 1 and 2 seconds, using an ordinary watch. To examine the effect of this error on the computed azimuth of a circumpolar star (confining the discussion to the northern hemisphere and to north circumpolars), let $A$ = azimuth from the north, $\phi$ = latitude of the observer, $t$ = hour angle of star, and $\delta$ = its declination.

Then

$$-\tan A = \frac{\sin t}{\cos\phi\tan\delta - \sin\phi\cos t} \tag{1}$$

Differentiating with respect to the time,

$$-\frac{d}{dt}(\tan A) = \frac{\cos\phi\tan\delta\cos t - \sin\phi}{(\cos\phi\tan\delta - \sin\phi\cos t)^2} \tag{2}$$

(a) *At culmination*, $t$ being 0° or 180°,

$$-\frac{dA}{dt} = \frac{1}{\cos\phi\tan\delta - \sin\phi} \tag{3}$$

Taking $dt = 1$ second of time and $\delta = 88°\ 55'$, we have

AZIMUTH ERROR PER SECOND OF TIME ERROR.

| N. Lat. | Azimuth Error | N. Lat. | Azimuth Error |
|---|---|---|---|
| 10° | 0″.31 | 50° | 0″.49 |
| 20 | 0.33 | 60 | 0.63 |
| 30 | 0.36 | 70 | 0.94 |
| 40 | 0.41 | | |

(b) *At elongation.*

By equating the second member of (2) to zero we find that elongation occurs when

$$\cos t = \tan\phi\cot\delta;$$

that is, when $t$ is a little less than $6^h$ or a little greater than $18^h$.

Therefore at elongation

$$-\frac{d}{dt}(\tan A) = 0 \tag{4}$$

PRINCIPLES OF OBSERVING.—*The error in azimuth due to error in observed time is a maximum at culminations and a minimum at elongations.*

*At elongations the azimuth is free of error due to time error, and for circumpolars the error is small even in the most unfavorable case, at culminations.*

*Error due to uncertainty in latitude.*

Uncertainty in latitude may be due to absence of a refined determination of the station, or to "station error" arising from unequal distri-

bution of matter in the earth's crust, or from remoteness of connection with the origin of co-ordinates in a triangulation system.

Differentiating (1) with respect to the latitude,

$$-\frac{d}{d\phi}(\tan A) = \sin t \frac{\sin\phi\tan\delta + \cos\phi\cos t}{(\cos\phi\tan\delta - \sin\phi\cos t)^2} \quad (5)$$

(a) *At culmination,* $t$ being 0° or 180°,

$$\frac{d}{d\phi}(\tan A) = 0 \quad (6)$$

(b) *At elongation,* when $\cos t = \cot\delta\tan\phi$. Substituting in (5),

$$-\frac{d}{d\phi}(\tan A) = \sin t \frac{\sin\phi(\tan\delta + \cot\delta)}{(\tan\delta\cos\phi - \cot\delta\sin\phi\tan\phi)^2} \quad (7)$$

With sufficient accuracy (not affecting the 5th decimal place for Polaris when the latitude is 30°) we may take $\sin t = 1$ and $\cot\delta = 0$; whence (7) reduces to

$$\frac{dA}{d\phi} = -\cos^2 A \frac{\tan\phi}{\cos\phi\tan\delta} \quad (8)$$

The following table illustrates the magnitude and variation of this error for observations on a star of declination 88° 50′ when the uncertainty in latitude is 1 mile or 1 minute of arc, taken as a convenient unit. The factor $\cos^2 A$, very nearly equal to 1 and changing slowly, might have been disregarded, but instead a convenient approximation to it has been used, corresponding to $t = 6^h$.

AZIMUTH ERROR PER MILE OF LATITUDE ERROR.

| N. Lat. | Azimuth Error | N. Lat. | Azimuth Error |
|---|---|---|---|
| 10° | 0″.22 | 50° | 2″.26 |
| 20 | 0.47 | 60 | 4.23 |
| 30 | 0.81 | 70 | 9.78 |
| 40 | 1.34 | | |

PRINCIPLES OF OBSERVING.—*The error in azimuth due to uncertainty in latitude is a minimum at culminations and a maximum at elongations.*

*At culminations the azimuth is free from error due to latitude error.*

*At elongations the error in azimuth due to latitude error is small for low latitudes, but increases rapidly with the latitude.*

It would appear from the foregoing principles that it is good practice in observing for azimuth to choose several circumpolar stars well distributed about the pole as to hour angles, and to observe on them in rapid succession, preceding and following the azimuth observations by time sets. The latter need not be as elaborate as in longitude work—usually two stars on either side of the zenith will suffice, or more will be needed if the time instrument is not in the meridian closely. In any event the transits of time stars should be reduced by their azimuth factors.

*The two-theodolite method of observing for azimuth.*

The writer has used this method for some years, and finds that it gives excellent results. Theodolite A is set up over the center of the station and is used for the azimuth measurements. Theodolite B is set up a few feet away and its zero is placed in the approximate meridian

AZIMUTH OF 51 H. CEPHEI, JAN. 1, 1921.

| 1st Quad. | From North toward West | | | | | | *2nd Quad. |
|---|---|---|---|---|---|---|---|
| h m | 5° N. | 10° N. | 15° N. | 20° N. | 25° N. | 30° N. | h m |
| | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | |
| 1:00 | 0 44 18 | 0 45 00 | 0 46 05 | 0 47 35 | 0 49 35 | 0 52 10 | 11:00 |
| 2:00 | 1 25 31 | 1 26 51 | 1 28 53 | 1 31 48 | 1 35 33 | 1 40 28 | 10:00 |
| 3:00 | 2 00 50 | 2 02 36 | 2 05 26 | 2 09 20 | 2 14 35 | 2 21 24 | 9:00 |
| 3:30 | 15 34 | 17 26 | 20 30 | 24 50 | 30 38 | 38 10 | 8:30 |
| 4:00 | 27 49 | 29 52 | 33 08 | 37 57 | 44 00 | 52 05 | 8:00 |
| 15 | 33 02 | 35 07 | 38 27 | 43 13 | 49 36 | 57 55 | 45 |
| 30 | 37 27 | 39 42 | 43 05 | 47 57 | 54 49 | 3 02 57 | 30 |
| 45 | 41 29 | 43 35 | 46 56 | 51 56 | 2 58 33 | 07 17 | 15 |
| 5:00 | 44 41 | 46 44 | 50 13 | 55 11 | 3 01 52 | 10 32 | 7:00 |
| 15 | 47 10 | 49 14 | 52 41 | 57 40 | 04 23 | 13 09 | 45 |
| 30 | 48 56 | 50 59 | 54 25 | 59 23 | 06 06 | 14 53 | 30 |
| 45 | 49 58 | 51 59 | 55 23 | 3 00 20 | 07 01 | 15 47 | 15 |
| 6:00 | 2 50 17.2 | 2 52 15.1 | 2 55 36.8 | 3 00 30.0 | 3 07 08.6 | 3 15 49.8 | 6:00 |
| W. E. | 17.3 | 15.8 | 38.3 | 31.9 | 11.5 | 54.6 | W. E. |

Intervals of Western Elongation before $6^h$ and of Eastern Elongation after $18^h$

| m s | m s | m s | m s | m s | m s |
|---|---|---|---|---|---|
| 0 59.4 | 1 59.5 | 3 01.9 | 4 07.2 | 5 16.7 | 6 32.1 |

| h m | 35° N. | 40° N. | 45° N. | 50° N. | 55° N. | 60° N. | h m |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | |
| 1:00 | 0 55 30 | 0 59 45 | 1 05 15 | 1 12 28 | 1 22 15 | 1 35 48 | 11:00 |
| 2:00 | 1 46 48 | 1 54 54 | 2 05 22 | 2 19 05 | 2 37 29 | 3 03 11 | 10:00 |
| 3:00 | 2 30 08 | 2 41 20 | 55 46 | 3 14 40 | 3 39 59 | 4 15 05 | 9:00 |
| 3:30 | 47 50 | 3 00 13 | 3 16 08 | 37 03 | 4 04 57 | 43 32 | 8:30 |
| 4:00 | 3 02 29 | 15 47 | 32 56 | 55 19 | 25 11 | 5 06 23 | 8:00 |
| 15 | 08 35 | 22 14 | 39 51 | 4 02 49 | 33 27 | 15 37 | 45 |
| 30 | 13 51 | 27 48 | 45 46 | 09 12 | 40 26 | 23 22 | 30 |
| 45 | 18 15 | 32 26 | 50 51 | 14 28 | 46 08 | 29 37 | 15 |
| 5:00 | 21 46 | 35 58 | 54 33 | 18 35 | 50 32 | 34 21 | 7:00 |
| 15 | 24 25 | 38 51 | 57 24 | 21 33 | 53 39 | 37 36 | 45 |
| 30 | 26 10 | 40 38 | 59 12 | 23 23 | 55 28 | 39 20 | 30 |
| 45 | 27 02 | 41 27 | 59 58 | 24 03 | 56 00 | 39 37 | 15 |
| 6:00 | 3 27 00.6 | 3 41 19.4 | 3 59 42.8 | 4 23 36.6 | 4 55 16.2 | 5 38 27.5 | 6:00 |
| W. E. | 08.0 | 30.5 | 4 00 00.2 | 24 03.9 | 56 00.2 | 39 41.2 | W. E. |

Intervals of Western Elongation before $6^h$ and of Eastern Elongation after $18^h$

| m s | m s | m s | m s | m s | m s |
|---|---|---|---|---|---|
| 7 55.6 | 9 30.0 | 11 19.3 | 13 29.8 | 16 10.7 | 19 37.4 |

The apparent motion of the star is: Upper culmination at $0^h$, western elongation at $6^h$, lower culmination at $12^h$, and eastern elongation at $18^h$.

by any of the methods in common use. It is provided with a full vertical circle and with a prismatic eye-piece that facilitates pointings up to or beyond 75°; and is in fact used as a transit instrument to find the clock error on local sidereal time before and after each azimuth set.

The advantages of this method are:

It obviates the transportation of time from a ship or other source—

*The angles of the table are repeated *approximately* in all quadrants as follows:

In the second quadrant, westerly, corresponding to hour angles $12^h - t$.
" " third " easterly, " " " " $12^h + t$.
" " fourth " easterly, " " " " $24^h - t$.

Computed with 7-place tables for declination 87° 10′ 21″.6, N.

the observations, then, are independent of a source less refined than the observations themselves.

The clock correction is known, not for a single point of time, but continuously throughout the period of observing.

The clock rate is carried for only a brief interval—between time sets.

*The use of previously prepared tables.*

A precise azimuth should be based on three or four observations on circumpolars. It requires no more time and trouble to find the clock error and rate for several azimuth observations than for one. It pays to go into the field with finder angles prepared for the latitude of the station and for the approximate day. These finder angles are simply computed azimuths of the stars to be observed on for azimuth, for the particular latitude of observation and for suitable intervals of hour angle—like one column of the table of azimuths of 51 H. Cephei, here given for illustration for the date Jan. 1, 1921. They are used in the following manner:

Having a continuously known clock correction, the azimuth of the star about to be observed is found by interpolation. Combining with this the approximate azimuth of the mark, the approximate angle between mark and star is known. The assistant writes this angle down and finds its multiples and multiples plus 180°, applying a small correction to each, if necessary, after the first pointing. He calls out these angles to the observer as they are needed. The observer, instead of sweeping for the star, sets off the finder angle on the plate, elevates the telescope to the proper altitude, easily estimated from the star's hour angle, and immediately finds the star in the field. By this means it is easy to find even a faint star quickly and with certainty as to its identity. There is, of course, a considerable advantage on the score of accuracy in turning the angles quickly, as in all other triangulation work.

The azimuths of 51 H. Cephei are given here to supplement, to a limited extent, the very complete azimuths of Polaris for all hour angles given in the *American Ephemeris and Nautical Almanac;* and for another reason associated with the construction of field tables. This star occupies a mean place among the four circumpolars usually chosen for azimuth observations—a position corresponding to that of the central meridian in chart construction. Let us therefore project these four circumpolars on the horizontal plane, as in measuring azimuth, and refer their azimuths, not at the same moments of time but at the same hour angles, to the azimuth of the central one, 51 H. Cephei. The result, for Jan. 1, 1921, is exhibited in the following table of ratios of azimuths of Polaris, 39 H. Cephei, and δ Ursae Minoris to those of 51 H. Cephei. We find that for similar hour angles the stars on either side of the central one preserve a nearly constant azimuth ratio to the azimuth of the central star, and that *this ratio is very nearly equal,* in each case, *to the ratio of polar distances.* The variation in

ratio is not too great to be of service in the construction of tables of finder angles. For first we may compute the azimuths of 51 H. Cephei for suitable hour angles, then the ratio of polar distances for each star, and finally multiply the azimuths of 51 H. Cephei by these ratios to give the azimuths of the other stars at corresponding hour angles (in the first quadrant). For greater accuracy find the ratio of azimuths also for $t = 1$ hour, and apply interpolated ratios between 1 hour and 6 hours.

RATIO OF AZIMUTHS OF CERTAIN CIRCUMPOLARS TO THE AZIMUTH OF 51 H. CEPHEI AT THE SAME HOUR ANGLES

| | Ratio of Polar Dist. | t | North Latitude 10° | 20° | 30° | 40° | 50° | 60° |
|---|---|---|---|---|---|---|---|---|
| Polaris | | 1h00 | 0.390 | 0.388 | 0.386 | 0.383 | 0.379 | 0.372 |
| | | 3:30 | 0.392 | 0.391 | 0.389 | 0.387 | 0.385 | 0.381 |
| | 0.393 | 6:00 | 0.393 | 0.393 | 0.393 | 0.393 | 0.394 | 0.394 |
| 39 H. Cephei | | 1:00 | 1.105 | 1.106 | 1.108 | 1.109 | 1.111 | 1.114 |
| | | 3:30 | 1.105 | 1.105 | 1.106 | 1.107 | 1.108 | 1.110 |
| | 1.104 | 6:00 | 1.104 | 1.104 | 1.104 | 1.104 | 1.104 | 1.103 |
| δ Urs. Min. | | 1:00 | 1.199 | 1.202 | 1.204 | 1.207 | 1.212 | 1.219 |
| | | 3:30 | 1.198 | 1.200 | 1.201 | 1.204 | 1.206 | 1.202 |
| | 1.197 | 6:00 | 1.197 | 1.197 | 1.197 | 1.197 | 1.197 | 1.196 |

It is not advisable to use Polaris as a star of reference in this way. It is too near the "edge of the map," so that the distortion for the outermost stars, as δ Ursae Minoris, would be excessive.

It will be noted that in the table of ratios the increase, with increase of latitude, of the 6-hour factors for Polaris, closer to the pole than the central star, and the decrease of the corresponding factors for 39 H. Cephei and δ Ursae Minoris, farther from the pole than the central star, are due to the fact that the stars are past elongation at 6 hours. The effect is quite pronounced in the case of the star farthest from the pole.

Hydrographic Surveyor, Navy Dept.,
450 Irving St., Northwest, Washington, D. C.

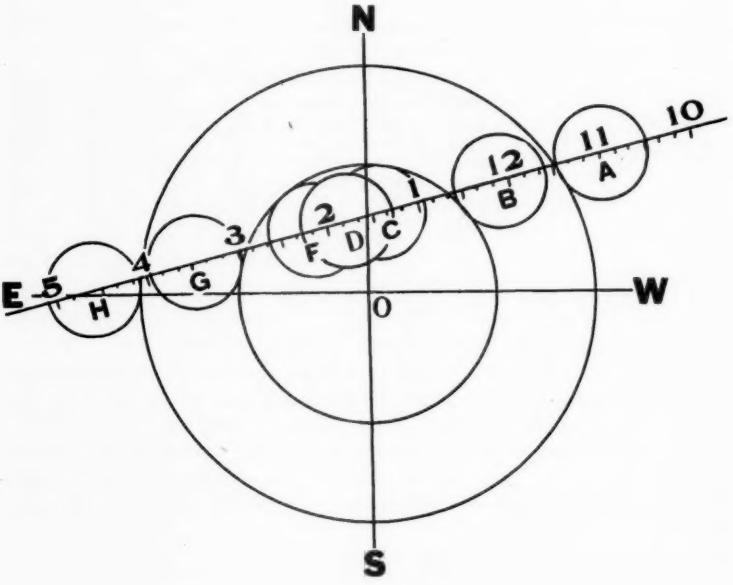
## TOTAL ECLIPSE OF THE MOON 1921 APRIL 21-22.

By WILLIAM F. RIGGE.

A total eclipse of the Moon will occur on the night of April 21-22. It will be completely visible all over the United States, although the hours are rather late. The annexed drawing will give the particulars.

The largest circle represents the Earth's penumbra and the next in size its umbra or shadow at the place where the Moon will cross them, N S E W being the cardinal points. The long oblique line is the relative path of the Moon, and the small circles on it represent the

Moon at important moments. On the 21st at 10:57 P. M., Central Time, when its center is at A, the Moon enters Penumbra. At 12:03 A. M. on the 22nd, when its center is at B, the Moon enters Shadow. At C at 1:23 the Total Eclipse begins. At D at 1:44 we have the Middle of the Eclipse. At F at 2:05 the Total Eclipse ends. At G at 3:26 the Moon leaves Shadow, and at H at 4:32 the Moon leaves Penumbra.



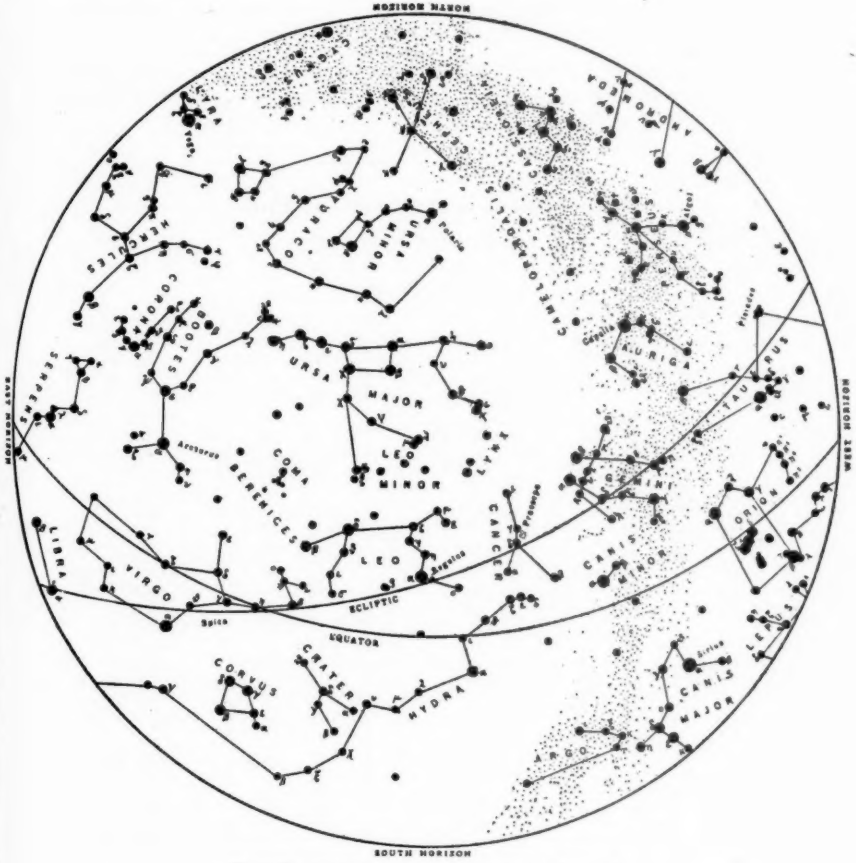

The magnitude of the eclipse is 1.074 or about 7 per cent more than total, which means that the Moon penetrates 7 per cent or one-fourteenth more than its own diameter into the shadow, as the figure plainly shows when the Moon is at D.

The duration of totality will be 42 minutes, from 1:23 to 2:05 A. M. During this time the Moon may either disappear from view so completely that in its stead there will be an absolutely empty space devoid of all stars like a hole or a tunnel in the sky, or it may easily be seen shining with a beautiful dull copper color. This complete or incomplete disappearance of the Moon cannot be predicted, because it depends upon the cloudy or clear condition of the sunrise and sunset circle of the Earth at the time, through which the Sun's rays either cannot penetrate or are allowed free passage, so that by refraction they may be bent into the shadow cone and by selective absorption be tinted with sunrise and sunset colors.

## PLANET NOTES AND PHENOMENA FOR APRIL.

The first eclipse of the year, an annular eclipse of the sun, occurs on the 7th. The path and circumstances of this eclipse can be found in the January number.

A total eclipse of the moon will occur on the night of April 21-22. As this eclipse will be generally visible throughout North America it should prove of considerable interest. The moon enters the umbra at 3 minutes past midnight, the middle of the eclipse occurs at $1^h\ 44^m$ A. M. and the moon leaves the umbra at $3^h\ 26^m$ A. M. on April 22, Central Standard Time.




THE CONSTELLATIONS AT 9:00 P. M. APRIL 1.

The phases of the *moon* will be as follows:

| | | | | | |
|---|---|---|---|---|---|
| New Moon | April | 8 | at 3: 5.2 | A.M. | C.S.T. |
| First Quarter | | 15 | " 4:11.6 | " | " |
| Full Moon | | 22 | " 1:49.4 | " | " |
| Last Quarter | | 29 | " 10: 8.7 | P.M. | " |

*Mercury* will be visible during the first few days of the month in the east before sunrise as it will be at greatest western elongation on the 30th of March.

*Venus* will approach the sun very rapidly and reach inferior conjunction on the 22nd. It will be interesting to watch the crescent phase during this time.

*Mars* will be too near the sun for observation.

*Jupiter* and *Saturn* will be in fine position for early evening observation, both planets being in the eastern part of Leo. The satellite phenomena will be found elsewhere in this issue.

*Uranus* will be in Aquarius and far enough from the sun to be visible in the morning sky before sunrise after the middle of the month.

*Neptune* will be in Cancer and approaching quadrature. The planet will be stationary on the 21st and therefore not easily detected unless sufficient magnification is used to show its disk.

---

## Phenomena of Jupiter's Satellites.

VISIBLE AT WASHINGTON.
[From the *American Ephemeris.*]
CENTRAL STANDARD TIME.

| 1921 | d | h | m | | | | d | h | m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. | 1 | 9 | 55 | II | Tr. I. | Apr. | 14 | 9 | 14 | I | Tr. E. |
| | | 11 | 12 | II | Sh. I. | | | 10 | 6 | I | Sh. E. |
| | | 12 | 44 | II | Tr. E. | | 15 | 7 | 14 | I | Ec. R. |
| | | 14 | 2 | II | Sh. E. | | 16 | 12 | 41 | III | Oc. D. |
| | 2 | 11 | 42 | III | Ec. R. | | 17 | 9 | 40 | II | Oc. D. |
| | 3 | 9 | 11 | II | Ec. R. | | 19 | 6 | 36 | II | Tr. E. |
| | 4 | 13 | 24 | I | Oc. D. | | | 8 | 31 | II | Sh. E. |
| | 5 | 9 | 30 | IV | Sh. E. | | 20 | 6 | 35 | III | Sh. I. |
| | | 10 | 44 | I | Tr. I. | | | 9 | 45 | III | Sh. E. |
| | | 11 | 27 | I | Sh. I. | | | 11 | 25 | I | Oc. D. |
| | | 13 | 0 | I | Tr. E. | | 21 | 8 | 47 | I | Tr. I. |
| | | 13 | 43 | I | Sh. E. | | | 9 | 46 | I | Sh. I. |
| | 6 | 7 | 50 | I | Oc. D. | | | 11 | 2 | I | Tr. E. |
| | | 10 | 51 | I | Ec. R. | | | 12 | 1 | I | Sh. E. |
| | 7 | 7 | 26 | I | Tr. E. | | 22 | 9 | 9 | I | Ec. R. |
| | | 8 | 12 | I | Sh. E. | | 23 | 6 | 29 | I | Sh. E. |
| | 8 | 12 | 14 | II | Tr. I. | | 24 | 12 | 3 | II | Oc. D. |
| | | 13 | 48 | II | Sh. I. | | 26 | 8 | 19 | II | Sh. I. |
| | 9 | 9 | 12 | III | Oc. D. | | | 9 | 1 | II | Tr. E. |
| | | 12 | 26 | III | Oc. R. | | | 11 | 7 | II | Sh. E. |
| | | 12 | 28 | III | Ec. D. | | 27 | 9 | 28 | III | Tr. E. |
| | 10 | 7 | 18 | II | Oc. D. | | | 10 | 35 | III | Sh. I. |
| | | 11 | 47 | II | Ec. R. | | | 13 | 15 | I | Oc. D. |
| | 12 | 12 | 31 | I | Tr. I. | | 28 | 10 | 36 | I | Tr. I. |
| | | 13 | 22 | I | Sh. I. | | | 11 | 40 | I | Sh. I. |
| | 13 | 7 | 50 | IV | Oc. D. | | | 12 | 51 | I | Tr. E. |
| | | 9 | 37 | I | Oc. D. | | 29 | 7 | 42 | I | Oc. D. |
| | | 11 | 41 | IV | Oc. R. | | | 11 | 4 | I | Ec. R. |
| | | 12 | 46 | I | Ec. R. | | 30 | 7 | 19 | I | Tr. E. |
| | 14 | 6 | 58 | I | Tr. I. | | | 8 | 24 | I | Sh. E. |
| | | 7 | 51 | I | Sh. I. | | | 10 | 16 | IV | Ec. D. |

NOTE:—I. denotes ingress; E., egress; D., disappearance; R., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

## Occultations Visible at Washington.

[*From the American Ephemeris.*]

| Date 1921 | Star's Name | Magnitude | IMMERSION. Washington M.T. | IMMERSION. Angle E from N | EMERSION. Washington M.T. | EMERSION. Angle E from N | Duration |
|---|---|---|---|---|---|---|---|
| | | | h m | ° | h m | ° | h m |
| Apr. 11 | 68 Tauri | 4.3 | 7 10 | 72 | 8 10 | 288 | 1 0 |
| 14 | 68 Gemin. | 5.2 | 12 5 | 60 | 12 42 | 327 | 0 37 |
| 16 | ω Leonis | 5.5 | 12 33 | 96 | 13 28 | 305 | 0 55 |
| 20 | *g* Virginis | 5.6 | 14 56 | 88 | 15 58 | 306 | 1 2 |
| 27 | ρ Sagittarii | 4.0 | 16 49 | 149 | 17 16 | 182 | 0 27 |

## Saturn's Satellites.

Greatest elongations visible in the United States.

[From the *American Ephemeris.*]

CENTRAL STANDARD TIME.

I. Mimas. Period $0^d\ 22^h.6$.

| 1921 | d | h | | d | h | | d | h | | d | h | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. | 1 | 10.2 | W | Apr. 8 | 11.8 | E | Apr. 15 | 13.4 | W | Apr. 23 | 13.7 | E |
| | 2 | 8.8 | W | 9 | 10.4 | E | 16 | 12.0 | W | 24 | 12.3 | E |
| | 3 | 7.4 | W | 10 | 9.0 | E | 17 | 10.6 | W | 25 | 10.9 | E |
| | 4 | 6.0 | W | 11 | 7.6 | E | 18 | 9.3 | W | 26 | 9.5 | E |
| | 4 | 17.3 | E | 12 | 6.3 | E | 19 | 7.9 | W | 27 | 8.1 | E |
| | 5 | 16.0 | E | 12 | 17.6 | W | 20 | 6.5 | W | 28 | 6.8 | E |
| | 6 | 14.6 | E | 13 | 16.2 | W | 21 | 16.4 | E | 29 | 16.7 | W |
| | | | | 14 | 14.8 | W | 22 | 15.0 | E | 30 | 15.3 | W |

II. Enceladus. Period $1^d\ 8^h.9$.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. | 2 | 8.7 | E | Apr. 9 | 5.1 | E | Apr. 16 | 1.5 | E | Apr. 22 | 21.9 | E |
| | 3 | 17.5 | E | 10 | 13.9 | E | 17 | 10.4 | E | 24 | 6.8 | E |
| | 5 | 2.4 | E | 11 | 22.8 | E | 18 | 19.2 | E | 25 | 15.6 | E |
| | 6 | 11.3 | E | 13 | 7.7 | E | 20 | 4.1 | E | 27 | 0.5 | E |
| | 7 | 20.2 | E | 14 | 16.6 | E | 21 | 13.0 | E | 28 | 9.4 | E |
| | | | | | | | | | | 29 | 18.3 | E |

III. Tethys. Period $1^d\ 21^h.3$.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. | 1 | 22.9 | E | Apr. 9 | 12.1 | E | Apr. 17 | 1.3 | E | Apr. 24 | 14.5 | E |
| | 3 | 20.2 | E | 11 | 9.4 | E | 18 | 22.6 | E | 26 | 11.8 | E |
| | 5 | 17.5 | E | 13 | 6.7 | E | 20 | 19.9 | E | 28 | 9.1 | E |
| | 7 | 14.8 | E | 15 | 4.0 | E | 22 | 17.2 | E | 30 | 6.4 | E |

IV. Dione. Period $2^d\ 17^h.7$.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. | 2 | 5.2 | E | Apr. 10 | 10.2 | E | Apr. 18 | 15.2 | E | Apr. 26 | 20.2 | E |
| | 4 | 22.8 | E | 13 | 3.8 | E | 21 | 8.8 | E | 29 | 13.8 | E |
| | 7 | 16.5 | E | 15 | 21.5 | E | 24 | 2.5 | E | | | |

V. Rhea. Period $4^d\ 12^h\ 5$.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. | 2 | 20.8 | E | Apr. 11 | 21.4 | E | Apr. 20 | 22.2 | E | Apr. 29 | 22.9 | E |
| | 7 | 9.1 | E | 16 | 9.8 | E | 25 | 10.5 | E | | | |

VI. Titan. Period $15^d\ 23^h.3$.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. | 4 | 19.3 | E | Apr. 12 | 14.5 | W | Apr. 20 | 17.2 | E | Apr. 28 | 12.4 | W |

VII. Hyperion. Period $21^d\ 7^h.6$.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Apr. 11 | 0.9 | E | Apr. 20 | 10.6 | W | | | |

VIII. Iapetus. Period $79^d\ 22^h.1$.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr. | | | | 12 | 21.1 | W | | | | | | |

IX. Phoebe. Period $523^d\ 15^h.6$.

| | α Ph.—α Sat. | | | δ Ph.—δ Sat. | | | α Ph.—α Sat. | | | δ Ph.—δ Sat. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | m | s | ′ | ″ | | | m | s | ′ | ″ | |
| Apr. 1 | +0 | 54.8 | | −7 | 42 | Apr. 15 | +1 | 10.8 | | −9 | 23 | |
| 3 | 0 | 57.2 | | 7 | 58 | 17 | 1 | 12.9 | | 9 | 35 | |
| 5 | 0 | 59.6 | | 8 | 13 | 19 | 1 | 14.9 | | 9 | 47 | |
| 7 | 1 | 2.0 | | 8 | 28 | 21 | 1 | 16.8 | | 9 | 58 | |
| 9 | 1 | 4.3 | | 8 | 42 | 23 | 1 | 18.6 | | 10 | 8 | |
| 11 | 1 | 6.5 | | 8 | 56 | 25 | 1 | 20.3 | | 10 | 18 | |
| 13 | +1 | 8.7 | | −9 | 10 | 27 | 1 | 22.0 | | 10 | 28 | |
| | | | | | | 29 | +1 | 23.6 | | −10 | 37 | |

NOTE:—E, Eastern Elongation; I, Inferior Conjunction (south of planet); W, Western Elongation; S, Superior Conjunction (north of planet).

## VARIABLE STARS.

### Minima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract $5^h$; Central Standard time $6^h$, etc.

| Star | R.A. 1900 | Decl. 1900 | Magnitude | Approx. Period | Greenwich mean times of minima in 1921 April | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h m | ° ′ | | d h | d h | d h | d h | d h | d h | d h | d h | d h |
| SY Androm. | 0 08.0 | +43 09 | 9.5—13.0 | 34 21.8 | 8 8 | | | | | | | |
| RT Sculptor. | 31.5 | —26 13 | 9.6—10.5 | 0 12.3 | 3 13 | 11 5 | 18 22 | 26 14 | | | | |
| UU Androm. | 38.5 | +30 24 | 10.7—11.9 | 1 11.7 | 5 8 | 12 18 | 20 5 | 27 15 | | | | |
| U Cephei | 0 53.4 | +81 20 | 7.0— 9.0 | 2 11.8 | 5 7 | 12 18 | 20 6 | 27 17 | | | | |
| Z Persei | 2 33.7 | +41 46 | 9.4—12 | 3 01.4 | 2 19 | 8 22 | 21 4 | 27 6 | | | | |
| TW Cassiop. | 37.6 | +65 19 | 8.2— 9.0 | 1 10.3 | 3 1 | 10 4 | 17 8 | 24 11 | | | | |
| RY Persei | 39.0 | +47 43 | 8.0—10.3 | 6 20.7 | 1 0 | 7 21 | 21 14 | 28 11 | | | | |
| RZ Cassiop. | 39.9 | +69 13 | 6.9— 8.1 | 1 04.7 | 6 16 | 13 20 | 21 0 | 28 4 | | | | |
| TX Cassiop. | 44.4 | +62 22 | 9.4—10.1 | 2 22.2 | 3 22 | 12 17 | 21 11 | 30 6 | | | | |
| ST Persei | 53.7 | +38 47 | 8.5—10.5 | 2 15.6 | 5 22 | 13 20 | 21 19 | 29 18 | | | | |
| RX Cassiop. | 2 58.8 | +67 11 | 8.6— 9.1 | 32 07.6 | | | | 30 20 | | | | |
| Algol | 3 01.7 | +40 34 | 2.3— 3.5 | 2 20.8 | 6 4 | 11 22 | 23 9 | 29 3 | | | | |
| RT Persei | 16.7 | +46 12 | 9.5—11.5 | 0 20.4 | 2 9 | 9 4 | 22 19 | 29 14 | | | | |
| λ Tauri | 55.1 | +12 12 | 3.3— 4.2 | 3 22.9 | 7 14 | 15 11 | 23 9 | | | | | |
| RW Tauri | 3 57.8 | +27 51 | 7.1—<11 | 2 18.5 | 3 7 | 11 14 | 19 22 | 28 5 | | | | |
| RV Persei | 4 04.2 | +33 59 | 9.5—11.0 | 1 23.4 | 1 19 | 9 17 | 17 14 | 25 11 | | | | |
| RW Persei | 13.3 | +42 04 | 8.8—11.0 | 13 04.8 | | 9 20 | | 23 1 | | | | |
| SZ Tauri | 31.4 | +18 20 | 7.2— 7.7 | 3 03.6 | 8 17 | 18 4 | 27 14 | | | | | |
| RS Cephei | 4 48.6 | +80 06 | 9.5—12.0 | 12 10.1 | | 11 14 | | 24 0 | | | | |
| TT Aurigæ | 5 02.8 | +39 27 | 7.8— 8.7 | 0 16.0 | 4 5 | 10 21 | 17 13 | 24 5 | | | | |
| RY Aurigæ | 11.5 | +38 13 | 10.7—11.7 | 2 17.5 | 6 17 | 14 22 | 23 2 | | | | | |
| RZ Aurigæ | 42.9 | +31 40 | 10.6—13.3 | 3 00.3 | 5 3 | 11 4 | 23 5 | 29 5 | | | | |
| SV Tauri | 45.8 | +28 05 | 9.4—11.0 | 2 04.0 | 3 2 | 11 18 | 20 11 | 29 2 | | | | |
| Z Orionis | 50.2 | +13 40 | 9.7—10.7 | 5 04.9 | 1 17 | 12 3 | 22 12 | | | | | |
| SV Gemin. | 54.6 | +24 28 | 9.8—<11 | 4 00.2 | 1 16 | 9 16 | 17 16 | 25 17 | | | | |
| RW Gemin. | 5 55.4 | +23 08 | 9.5—11.0 | 2 20.8 | 1 11 | 12 22 | 24 9 | 30 2 | | | | |
| U Columbæ | 6 11.2 | —33 03 | 9.2—10.0 | 2 19.2 | 5 10 | 11 0 | 22 5 | 27 20 | | | | |
| SX Gemin. | 22.0 | +20 37 | 10.8—11.5 | 1 08.8 | 4 20 | 13 1 | 21 6 | 29 11 | | | | |
| RW Monoc. | 29.3 | + 8 54 | 9.0—10.8 | 1 21.7 | 1 7 | 8 22 | 16 13 | 24 4 | | | | |
| RX Gemin. | 43.6 | +33 21 | 8.8— 9.6 | 12 05.0 | | 12 6 | | 24 12 | | | | |
| RU Monoc. | 6 49.4 | — 7 28 | 9.8—10.5 | 0 21.5 | 4 11 | 11 15 | 18 19 | 25 23 | | | | |
| R Can. Maj. | 7 14.9 | —16 12 | 5.8— 6.4 | 1 03.3 | 4 22 | 11 17 | 18 13 | 25 8 | | | | |
| RY Gemin. | 21.7 | +15 52 | 8.9—<10 | 9 07.2 | 6 12 | 15 19 | 25 2 | | | | | |
| Y Camelop. | 27.6 | +76 17 | 9.5—12 | 3 07.3 | 5 6 | 11 20 | 18 11 | 25 2 | | | | |
| TX Gemin. | 30.3 | +17 08 | 10.0—11.9 | 2 19.2 | 8 10 | 16 20 | 25 5 | | | | | |
| RR Puppis | 43.5 | —41 08 | 9.4—10.7 | 6 10.3 | 3 1 | 9 11 | 22 8 | 28 18 | | | | |
| V Puppis | 7 55.4 | —48 58 | 4.1— 4.8 | 1 10.9 | 8 2 | 15 9 | 22 16 | 29 22 | | | | |
| X Carinae | 8 29.1 | —58 53 | 7.9— 8.7 | 0 13.0 | 3 15 | 11 18 | 19 20 | 27 23 | | | | |
| S Cancri | 8 38.2 | +19 24 | 8.2—10 | 9 11.6 | 6 17 | 16 5 | 25 16 | | | | | |
| RX Hydræ | 9 00.8 | — 7 52 | 9.1—10.5 | 2 6.8 | 3 10 | 10 6 | 23 23 | 30 19 | | | | |
| S Velorum | 29.4 | —44 46 | 7.8— 9.3 | 5 22.4 | 2 7 | 8 5 | 20 2 | 26 0 | | | | |
| Y Leonis | 9 31.1 | +26 41 | 9.3—11.2 | 1 16.5 | 2 6 | 9 0 | 22 6 | 29 5 | | | | |
| RR Velorum | 10 17.8 | —41 36 | 10.0—10.9 | 1 20.5 | 3 18 | 11 4 | 18 14 | 26 0 | | | | |
| SS Carinæ | 10 54.2 | —61 23 | 12.2—12.8 | 3 07.2 | 2 2 | 8 17 | 21 22 | 28 12 | | | | |
| ST Urs. Maj. | 11 22.4 | +45 44 | 6.7— 7.2 | 8 19.2 | 7 10 | 16 5 | 25 0 | | | | | |
| RW Urs. Maj. | 35.4 | +52 34 | 10.3—11.4 | 7 07.9 | 3 10 | 10 18 | 18 2 | 25 10 | | | | |
| Z Draconis | 11 39.8 | +72 49 | 9.9—13.6 | 1 08.6 | 6 16 | 13 11 | 20 6 | 27 1 | | | | |
| RZ Centauri | 12 55.6 | —64 05 | 8.5— 8.9 | 1 21.0 | 2 16 | 10 4 | 17 16 | 25 4 | | | | |
| RS Can. Ven. | 13 06.3 | +36 28 | 7.5—12.5 | 4 19.1 | 2 10 | 12 0 | 21 14 | | | | | |
| SS Centauri | 07.2 | —63 37 | 8.8—10.4 | 2 11.5 | 8 0 | 15 11 | 22 21 | 30 8 | | | | |
| *133926* Hydræ | 13 39.0 | —26 23 | 8.6—12.7 | 2 21.5 | 2 20 | 8 15 | 20 5 | 26 0 | | | | |

**Minima of Variable Stars of Short Period**—Continued.

| Star | R.A. 1900 | | Decl. 1900 | | Magnitude | Approx. Period | | Greenwich mean times of minima in 1921 April | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h | m | ° | ′ | | d | h | d | h | d | h | d | h |
| δ Libræ | 14 | 55.6 | — 8 | 07 | 4.8— 6.2 | 2 | 07.9 | 2 | 12 | 9 | 12 | 23 | 11 | 30 | 10 |
| U Coronæ | 15 | 14.1 | +32 | 01 | 7.6— 8.7 | 3 | 10.9 | 2 | 11 | 9 | 9 | 23 | 4 | 30 | 2 |
| TW Draconis | 15 | 32.4 | +64 | 14 | 7.3— 8.9 | 2 | 19.3 | 7 | 22 | 16 | 8 | 24 | 18 | | |
| SS Librae | 15 | 43.4 | —15 | 14 | 9.3—11.5 | 0 | 18.4 | 5 | 18 | 13 | 10 | 21 | 2 | 28 | 17 |
| SW Ophiuchi | 16 | 11.1 | — 6 | 44 | 9.2—10.0 | 2 | 10.7 | 6 | 10 | 13 | 18 | 21 | 2 | 28 | 10 |
| SX Ophiuchi | | 12.6 | — 6 | 25 | 10.5—11.2 | 2 | 01.5 | 5 | 22 | 14 | 4 | 22 | 10 | 30 | 16 |
| R Aræ | | 31.1 | —56 | 48 | 6.8— 7.9 | 4 | 10.2 | 6 | 22 | 15 | 19 | 24 | 15 | | |
| TT Herculis | 16 | 49.9 | +17 | 00 | 8.9— 9.3 | 20 | 18.1 | 1 | 12 | 12 | 14 | 22 | 6 | | |
| TU Herculis | 17 | 09.8 | +30 | 50 | 9.5—12 | 2 | 06.4 | 7 | 14 | 14 | 9 | 21 | 4 | 28 | 0 |
| U Ophiuchi | | 11.5 | + 1 | 19 | 6.0— 6.7 | 0 | 20.1 | 3 | 16 | 12 | 1 | 20 | 10 | 28 | 20 |
| μ Herculis | | 13.6 | +33 | 12 | 4.6— 5.4 | 2 | 01.2 | 5 | 21 | 12 | 1 | 24 | 8 | 30 | 12 |
| TX Herculis | | 15.4 | +42 | 00 | 8.3— 9.0 | 1 | 00.7 | 4 | 5 | 10 | 9 | 22 | 17 | 28 | 22 |
| RV Ophiuchi | | 29.8 | + 7 | 19 | 9. —12 | 3 | 16.5 | 8 | 0 | 15 | 9 | 22 | 18 | 30 | 2 |
| SZ Herculis | | 36.0 | +33 | 01 | 9.5—10.3 | 0 | 19.6 | 2 | 0 | 10 | 5 | 18 | 9 | 26 | 13 |
| TX Scorpii | | 48.6 | —34 | 13 | 7.5— 8.2 | 0 | 22.6 | 4 | 8 | 11 | 21 | 19 | 9 | 26 | 22 |
| UX Herculis | | 49.7 | +16 | 57 | 8.8—10.5 | 1 | 13.2 | 2 | 1 | 9 | 19 | 17 | 13 | 25 | 7 |
| Z Herculis | | 53.6 | +15 | 09 | 7.1— 7.9 | 3 | 23.8 | 4 | 18 | 12 | 18 | 20 | 18 | 28 | 17 |
| WX Sagittarii | | 53.6 | —17 | 24 | 9.2—10.8 | 2 | 03.1 | 4 | 4 | 12 | 16 | 21 | 5 | 29 | 17 |
| WY Sagittarii | 17 | 54.9 | —23 | 1 | 9.5—10.6 | 4 | 16.0 | 6 | 15 | 15 | 23 | 25 | 7 | | |
| SX Draconis | 18 | 03.0 | +58 | 23 | 9.3—10.5 | 5 | 04.1 | 7 | 17 | 18 | 1 | 28 | 9 | | |
| RS Sagittarii | | 11.0 | —34 | 08 | 5.9— 6.3 | 2 | 10.0 | 2 | 8 | 9 | 14 | 16 | 20 | 24 | 2 |
| V Serpentis | | 11.1 | —15 | 34 | 9.5—11.1 | 3 | 10.9 | 7 | 11 | 14 | 18 | 21 | 6 | 28 | 4 |
| RZ Scuti | | 21.1 | — 9 | 15 | 7.4— 8.3 | 15 | 03.2 | 6 | 21 | | | 20 | 0 | | |
| RZ Draconis | | 21.8 | +58 | 50 | 9.5—10.2 | 0 | 13.2 | 2 | 16 | 9 | 20 | 17 | 0 | 24 | 4 |
| RX Herculis | | 26.0 | +12 | 32 | 7.0— 7.6 | 0 | 21.3 | 3 | 14 | 10 | 17 | 17 | 19 | 24 | 22 |
| SX Sagittarii | | 39.7 | —30 | 36 | 8.7— 9.8 | 2 | 01.8 | 3 | 11 | 11 | 18 | 20 | 2 | 28 | 9 |
| RR Draconis | | 40.8 | +62 | 34 | 9.3—13 | 2 | 19.9 | 5 | 2 | 13 | 14 | 22 | 2 | 30 | 13 |
| RS Scuti | | 43.7 | —10 | 21 | 9.3—10.3 | 0 | 15.9 | 5 | 9 | 12 | 1 | 18 | 16 | 25 | 8 |
| β Lyræ | | 46.4 | +33 | 15 | 3.4— 4.1 | 12 | 21.8 | | | 13 | 3 | | | 26 | 1 |
| U Scuti | 18 | 48.9 | —12 | 44 | 9.1— 9.6 | 0 | 22.9 | 1 | 11 | 9 | 3 | 16 | 18 | 24 | 9 |
| RX Draconis | 19 | 01.1 | +58 | 35 | 9.3—10.2 | 1 | 21.4 | 4 | 9 | 11 | 23 | 19 | 12 | 27 | 2 |
| RV Lyræ | | 12.5 | +32 | 15 | 11. —12.8 | 3 | 14.4 | 4 | 6 | 11 | 11 | 18 | 15 | 25 | 20 |
| RS Vulpec. | | 13.4 | +22 | 16 | 6.9— 8.0 | 4 | 11.4 | 2 | 5 | 11 | 4 | 20 | 2 | 29 | 1 |
| U Sagittæ | | 14.4 | +19 | 26 | 6.5— 9.0 | 3 | 09.1 | 2 | 19 | 9 | 13 | 23 | 1 | 29 | 20 |
| Z Vulpec. | | 17.5 | +25 | 23 | 7.3— 8.5 | 2 | 10.9 | 7 | 20 | 15 | 5 | 22 | 13 | 29 | 22 |
| TT Lyræ | | 24.3 | +41 | 30 | 9.4—11.6 | 5 | 05.8 | 4 | 22 | 10 | 4 | 20 | 16 | 25 | 21 |
| UZ Draconis | | 26.1 | +68 | 44 | 9.0— 9.8 | 1 | 15.1 | 1 | 18 | 8 | 8 | 21 | 9 | 27 | 21 |
| SY Cygni | 19 | 42.7 | +32 | 28 | 10 —12 | 6 | 00.2 | 3 | 10 | 9 | 10 | 21 | 11 | 27 | 11 |
| WW Cygni | 20 | 00.6 | +41 | 18 | 9.3—13.4 | 3 | 07.6 | 4 | 0 | 10 | 15 | 23 | 21 | 30 | 13 |
| SW Cygni | | 03.8 | +46 | 01 | 9. —11.7 | 4 | 13.8 | 5 | 2 | 14 | 6 | 23 | 10 | | |
| VW Cygni | | 11.4 | +34 | 12 | 9.8—11.8 | 8 | 10.3 | 9 | 4 | 17 | 20 | 26 | 6 | | |
| RW Capric. | | 12.2 | —17 | 59 | 8.8—10.6 | 3 | 09.4 | 4 | 17 | 11 | 11 | 18 | 6 | 25 | 1 |
| UW Cygni | | 19.6 | +42 | 55 | 10.5—13 | 3 | 10.8 | 2 | 2 | 8 | 23 | 22 | 18 | 29 | 16 |
| V Vulpec. | | 32.3 | +26 | 15 | 8.2— 9.8 | 37 | 19.0 | | | | | 17 | 22 | | |
| W Delphini | | 33.1 | +17 | 56 | 9.4—12.1 | 4 | 19.4 | 3 | 6 | 12 | 20 | 22 | 11 | | |
| RR Delphini | | 38.9 | +13 | 35 | 10.5—11.8 | 4 | 14.4 | 7 | 7 | 16 | 12 | 25 | 17 | | |
| Y Cygni | | 48.1 | +34 | 17 | 7.1— 7.9 | 1 | 12.0 | 1 | 18 | 9 | 6 | 16 | 18 | 24 | 6 |
| WZ Cygni | | 49.3 | +38 | 27 | 9.9—10.8 | 0 | 14.0 | 1 | 6 | 8 | 20 | 16 | 10 | 24 | 1 |
| RR Vulpec. | 20 | 50.5 | +27 | 32 | 9.6—11.0 | 5 | 01.2 | 2 | 6 | 12 | 8 | 22 | 10 | | |
| VVCygni | 21 | 02.3 | +45 | 23 | 12.1—13.8 | 1 | 11.4 | 7 | 9 | 14 | 18 | 22 | 3 | 29 | 12 |
| AE Cygni | | 09.0 | +30 | 20 | 10.8—11.4 | 0 | 23.3 | 9 | 5 | 18 | 21 | 28 | 14 | | |
| RY Aquarii | | 14.8 | —11 | 14 | 8.8—10.4 | 1 | 23.2 | 5 | 12 | 13 | 8 | 21 | 5 | 29 | 2 |
| RT Lacertæ | 21 | 57.4 | +43 | 24 | 9.1—10.5 | 5 | 01.7 | 2 | 13 | 12 | 16 | 22 | 20 | | |
| UZ Cygni | | 55.2 | +43 | 52 | 8.9—11.6 | 31 | 07.3 | 7 | 4 | | | | | | |
| RW Lacertæ | 22 | 40.6 | +49 | 08 | 10.2—11.2 | 5 | 04.4 | 4 | 13 | 14 | 22 | 25 | 7 | 30 | 11 |
| 8.1914 Pegasi | | 51.7 | +32 | 41 | 10.0—10.6 | 5 | 06.4 | 3 | 5 | 13 | 18 | 24 | 7 | 29 | 13 |
| TT Androm. | 23 | 08.7 | +45 | 36 | 11.3—12.6 | 2 | 18.4 | 1 | 16 | 9 | 23 | 18 | 6 | 26 | 13 |
| Y Piscium | | 29.3 | + 7 | 22 | 9.0—12.0 | 3 | 18.3 | 7 | 19 | 15 | 8 | 22 | 21 | 30 | 9 |
| TW Androm. | 23 | 58.2 | +32 | 17 | 8.6—11.5 | 4 | 02.9 | 4 | 6 | 12 | 12 | 20 | 17 | 28 | 23 |

## Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5$^h$; Central Standard time 6$^h$, etc.

| Star | R.A. 1900 | | Decl. 1900 | | Magnitude | Approx. Period | | Greenwich mean times of maxima in 1921 April | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h | m | ° | ′ | | d | h | d | h | d | h | d | h | d | h |
| SX Cassiop. | 0 | 05.5 | +54 | 20 | 8.6— 9.2 | 36 | 13.7 | | | | | | | | |
| SY Cassiop. | 0 | 09.8 | +57 | 52 | 9.3— 9.9 | 4 | 1.7 | 7 | 7 | 15 | 11 | 23 | 14 | | |
| RR Ceti | 1 | 27.0 | + 0 | 50 | 8.3— 9.0 | 0 | 13.3 | 8 | 14 | 16 | 8 | 23 | 2 | | |
| RW Cassiop. | 1 | 30.7 | +57 | 15 | 8.9—11.0 | 14 | 19.2 | | | 10 | 3 | | | 24 | 22 |
| V Arietis | 2 | 09.6 | +11 | 46 | 8.3— 9.0 | 0 | 23.8 | 2 | 22 | 10 | 20 | 18 | 18 | 26 | 17 |
| SU Cassiop. | 2 | 43.0 | +68 | 28 | 6.5— 7.0 | 1 | 22.8 | 7 | 9 | 15 | 4 | 22 | 23 | 30 | 18 |
| TU Persei | 3 | 01.8 | +52 | 49 | 11.4—12.2 | 0 | 14.6 | 1 | 20 | 9 | 3 | 23 | 16 | 30 | 23 |
| RW Camelop. | 3 | 46.2 | +58 | 21 | 8.2— 9.4 | 16 | 00.0 | 5 | | | | 21 | | | |
| SX Persei | 4 | 10.2 | +41 | 27 | 10.4—11.2 | 4 | 07.0 | 7 | 16 | 16 | 6 | 24 | 19 | | |
| SV Persei | | 42.8 | +42 | 07 | 8.8— 9.6 | 11 | 03 1 | 3 | 6 | 14 | 9 | 25 | 12 | | |
| RX Aurigæ | 4 | 54.5 | +39 | 49 | 7.2— 8.1 | 11 | 15.0 | | | 11 | 16 | 23 | 7 | | |
| SX Aurigæ | 5 | 04.6 | +42 | 02 | 8.0— 8.7 | 1 | 12.8 | 5 | 21 | 13 | 13 | 21 | 5 | 28 | 21 |
| SY Aurigæ | | 05.5 | +42 | 41 | 8.4— 9.5 | 10 | 03.3 | 10 | 9 | 20 | 13 | 30 | 16 | | |
| Y Aurigae | | 21.5 | +42 | 21 | 8.6— 9.6 | 3 | 20.6 | 4 | 11 | 12 | 4 | 19 | 21 | 27 | 15 |
| RZ Gemin. | 5 | 56.6 | +22 | 15 | 9.1—10.0 | 5 | 12.7 | 1 | 2 | 5 | 15 | 17 | 16 | 28 | 18 |
| RS Orionis | 6 | 16.5 | +14 | 44 | 8.2— 8.9 | 7 | 13.6 | 4 | 7 | 11 | 20 | 19 | 10 | 26 | 23 |
| T Monoc. | | 19.8 | + 7 | 08 | 5.7— 6.8 | 27 | 00.3 | | | 8 | 14 | | | | |
| RT Aurigæ | | 23.0 | +30 | 33 | 5.1— 6.0 | 3 | 17.5 | 7 | 22 | 15 | 9 | 22 | 20 | 30 | 7 |
| RZ Camelop. | | 23.7 | +67 | 06 | 11.0—13.0 | 0 | 11.5 | 2 | 9 | 9 | 14 | 16 | 18 | 23 | 23 |
| W Gemin. | | 29.2 | +15 | 24 | 6.7— 7.5 | 7 | 22.0 | 1 | 9 | 9 | 8 | 17 | 5 | 25 | 4 |
| ζ Gemin. | 6 | 58.2 | +20 | 43 | 3.7— 4.3 | 10 | 03.7 | 4 | 14 | 10 | 17 | 24 | 21 | | |
| RU Camelop. | 7 | 10.9 | +69 | 51 | 8.5— 9.8 | 22 | 06.5 | 6 | 15 | | | 28 | 22 | | |
| RR Gemin. | 7 | 15.2 | +31 | 04 | 10.0—11.5 | 0 | 09.5 | 2 | 14 | 10 | 13 | 18 | 12 | 26 | 10 |
| V Carinæ | 8 | 26.7 | —59 | 47 | 7.4— 8.1 | 6 | 16.7 | 6 | 10 | 13 | 2 | 19 | 19 | 26 | 12 |
| T Velorum | 8 | 34.4 | —47 | 01 | 7.6— 8.5 | 4 | 15.3 | 8 | 19 | 18 | 2 | 27 | 8 | | |
| V Velorum | 9 | 19.2 | —55 | 32 | 7.5— 8.2 | 4 | 08.9 | 4 | 9 | 13 | 3 | 21 | 20 | 30 | 14 |
| Z Leonis | 9 | 46.4 | +27 | 22 | 7.9— 9.6 | 59 | 00.0 | 1 | | | | | | | |
| RR Leonis | 10 | 02.1 | +24 | 29 | 9.1—10.1 | 0 | 10.9 | 4 | 6 | 11 | 1 | 17 | 20 | 24 | 15 |
| SU Draconis | 11 | 32.2 | +67 | 53 | 8.9— 9.6 | 0 | 15.8 | 1 | 7 | 7 | 21 | 21 | 2 | 27 | 17 |
| S Muscæ | 12 | 07.4 | —69 | 36 | 6.4— 7.3 | 9 | 15.8 | 3 | 18 | 13 | 10 | 23 | 2 | | |
| SW Draconis | | 12.8 | +70 | 04 | 8.8— 9.6 | 0 | 13.7 | 4 | 0 | 12 | 0 | 19 | 23 | 27 | 23 |
| T Crucis | | 15.9 | —61 | 44 | 6.8— 7.6 | 6 | 17.6 | 3 | 20 | 10 | 13 | 17 | 7 | 24 | 0 |
| R Crucis | | 18.1 | —61 | 04 | 6.8— 7.9 | 5 | 19.8 | 6 | 2 | 11 | 22 | 23 | 14 | 29 | 9 |
| S Crucis | 12 | 48.4 | —57 | 53 | 6.5— 7.6 | 4 | 16.6 | 4 | 0 | 8 | 17 | 18 | 2 | 22 | 18 |
| W Virginis | 13 | 20.9 | — 2 | 52 | 8.7—10.4 | 17 | 06.5 | | | 14 | 13 | | | | |
| SS Hydræ | | 25.0 | —23 | 08 | 7.4— 8.1 | 8 | 04.8 | 2 | 14 | 10 | 19 | 19 | 0 | 27 | 5 |
| RV Urs. Maj. | 13 | 29.4 | +54 | 31 | 9.2— 9.9 | 0 | 11.2 | 3 | 2 | 10 | 2 | 17 | 3 | 24 | 3 |
| ST Virginis | 14 | 22.5 | — 0 | 27 | 10.3—11.4 | 0 | 09.9 | 2 | 15 | 10 | 20 | 19 | 1 | 27 | 6 |
| V Centauri | | 25.4 | —56 | 27 | 6.4— 7.8 | 5 | 11.9 | 2 | 23 | 8 | 11 | 19 | 11 | 24 | 23 |
| RS Bootis | | 29.3 | +32 | 11 | 8.9—10.0 | 0 | 09.1 | 5 | 15 | 13 | 4 | 20 | 17 | 28 | 6 |
| RU Bootis | 14 | 41.5 | +23 | 44 | 12.8—14.3 | 0 | 11.9 | 8 | 4 | 15 | 14 | 23 | 0 | 30 | 10 |
| R Triang. Austr. | 15 | 10.8 | —66 | 08 | 6.7— 7.4 | 3 | 09.3 | 3 | 4 | 9 | 22 | 23 | 12 | 30 | 6 |
| S Triang. Austr. | 15 | 52.2 | —63 | 29 | 6.4— 7.4 | 6 | 07.8 | 1 | 20 | 8 | 4 | 20 | 20 | 27 | 14 |
| S Normæ | 16 | 10.6 | —57 | 39 | 6.6— 7.6 | 9 | 18.1 | 2 | 16 | 12 | 11 | 22 | 5 | | |
| RW Draconis | | 33.7 | +58 | 03 | 9.6—10.8 | 0 | 10.6 | 4 | 13 | 13 | 10 | 22 | 6 | | |
| RV Scorpii | 16 | 51.8 | —33 | 27 | 6.7— 7.4 | 6 | 01.5 | 5 | 16 | 11 | 17 | 23 | 20 | 29 | 22 |
| X Sagittarii | 17 | 41.3 | —27 | 48 | 4.4— 5.0 | 7 | 00.3 | 2 | 1 | 9 | 1 | 23 | 2 | 30 | 2 |
| Y Ophiuchi | | 47.3 | — 6 | 07 | 6.1— 6.5 | 17 | 02.9 | 4 | 14 | | | 21 | 17 | | |
| W Sagittarii | 17 | 58.6 | —29 | 35 | 4.3— 5.1 | 7 | 14.3 | 5 | 7 | 12 | 21 | 20 | 11 | 28 | 1 |
| Y Sagittarii | 18 | 15.5 | —18 | 54 | 5.4— 6.2 | 5 | 18.6 | 4 | 5 | 9 | 23 | 21 | 13 | 27 | 7 |
| U Sagittarii | | 26.0 | —19 | 12 | 6.5— 7.3 | 6 | 17.9 | 5 | 22 | 12 | 16 | 19 | 9 | 26 | 3 |
| Y Scuti | | 32.6 | — 8 | 27 | 8.7— 9.2 | 10 | 08.3 | 4 | 3 | 14 | 12 | 24 | 20 | | |
| Y Lyræ | | 34.2 | +43 | 52 | 11.3—12.3 | 0 | 12.1 | 1 | 21 | 7 | 22 | 19 | 23 | 26 | 0 |
| RZ Lyræ | 18 | 39.9 | +32 | 42 | 9.9—11.2 | 0 | 12.3 | 1 | 18 | 6 | 21 | 20 | 4 | 26 | 7 |

**Maxima of Variable Stars of Short Period—Continued.**

| Star | R.A. 1900 | Decl. 1900 | Magnitude | Approx. Period | Greenwich mean times of maxima in 1921 April | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h m | ° ′ | | d h | d h | d h | d h | d h | | | | |
| RT Scuti | 18 44.1 | —10 30 | 9.1— 9.7 | 0 11.9 | 4 15 | 10 13 | 22 11 | 28 10 | | | | |
| κ Pavonis | 18 46.6 | —67 22 | 3.8— 5.2 | 9 02.2 | 4 11 | 13 13 | 22 15 | | | | | |
| U Aquilæ | 19 24.0 | — 7 15 | 6.2— 6.9 | 7 00.6 | 5 6 | 12 7 | 19 7 | 26 8 | | | | |
| XZ Cygni | 30.4 | +56 10 | 8.6— 9.3 | 0 11.2 | 5 18 | 12 18 | 19 18 | 26 18 | | | | |
| U Vulpec. | 32.2 | +20 07 | 6.5— 7.6 | 7 23.5 | 6 18 | 14 18 | 22 17 | | | | | |
| SU Cygni | 40.8 | +29 01 | 6.2— 7.0 | 3 20.3 | 6 5 | 13 22 | 21 15 | 29 7 | | | | |
| η Aquilæ | 47.4 | + 0 45 | 3.7— 4.5 | 7 04.2 | 5 20 | 13 0 | 20 4 | 27 8 | | | | |
| S Sagittæ | 51.5 | +16 22 | 5.6— 6.4 | 8 09.2 | 7 18 | 16 4 | 24 13 | | | | | |
| X Vulpec. | 19 53.3 | +26 17 | 9.5—10.5 | 6 07.7 | 4 16 | 11 0 | 23 15 | 29 23 | | | | |
| X Cygni | 20 39.5 | +35 14 | 6.0— 7.0 | 16 09.3 | | 11 2 | | 27 11 | | | | |
| T Vulpec. | 47.2 | +27 52 | 5.5— 6.1 | 4 10.5 | 3 0 | 11 21 | 20 18 | 29 15 | | | | |
| WY Cygni | 52.3 | +30 03 | 9.6—10.4 | 0 13.5 | 3 16 | 10 9 | 23 20 | 30 14 | | | | |
| RV Capric. | 55.9 | —15 37 | 9.2—10.1 | 0 10.7 | 5 17 | 12 10 | 19 3 | 25 20 | | | | |
| TX Cygni | 20 56.4 | +42 12 | 8.5— 9.7 | 14 17.4 | 6 2 | | 20 19 | | | | | |
| VY Cygni | 21 00.4 | +39 34 | 8.8— 9.5 | 7 20.6 | 4 2 | 11 23 | 19 20 | 27 16 | | | | |
| SW Aquarii | 10.2 | — 0 20 | 9.9—10.8 | 0 11.0 | 6 18 | 13 15 | 20 13 | 27 10 | | | | |
| VZ Cygni | 21 47.7 | +42 40 | 8.2— 9.2 | 4 20.7 | 1 20 | 11 13 | 21 6 | 26 3 | | | | |
| Y Lacertæ | 22 05.2 | +50 33 | 9.1— 9.6 | 4 07.8 | 8 23 | 17 14 | 26 6 | | | | | |
| δ Cephei | 25.5 | +57 54 | 3.7— 4.6 | 5 08.8 | 3 11 | 8 20 | 19 14 | 30 7 | | | | |
| Z Lacertæ | 36.9 | +56 18 | 8.2— 9.0 | 10 21.1 | 3 22 | 14 19 | 25 16 | | | | | |
| RR Lacertæ | 37.5 | +55 55 | 8.5— 9.2 | 6 10.1 | 6 5 | 12 15 | 19 1 | 25 12 | | | | |
| V Lacertae | 44.5 | +55 48 | 8.5— 9.5 | 4 23.6 | 1 8 | 11 7 | 21 6 | 26 6 | | | | |
| X Lacertæ | 22 45.0 | +55 54 | 8.2— 8.6 | 5 10.7 | 3 2 | 18 13 | 19 10 | 24 21 | | | | |
| SW Cassiop. | 23 03.7 | +58 11 | 9.2— 9.7 | 5 10.6 | 1 9 | 12 6 | 17 16 | 28 13 | | | | |
| RS Cassiop. | 32.6 | +61 52 | 9.0—11.0 | 6 07.1 | 5 16 | 11 23 | 24 13 | 30 21 | | | | |
| RY Cassiop. | 47.2 | +58 11 | 9.3—11.8 | 12 03.4 | 2 13 | 14 17 | 26 20 | | | | | |
| V Cephei | 23 51.7 | +82 38 | 6.0— 7.0 | 0 23.9 | 7 23 | 14 23 | 21 22 | 28 22 | | | | |

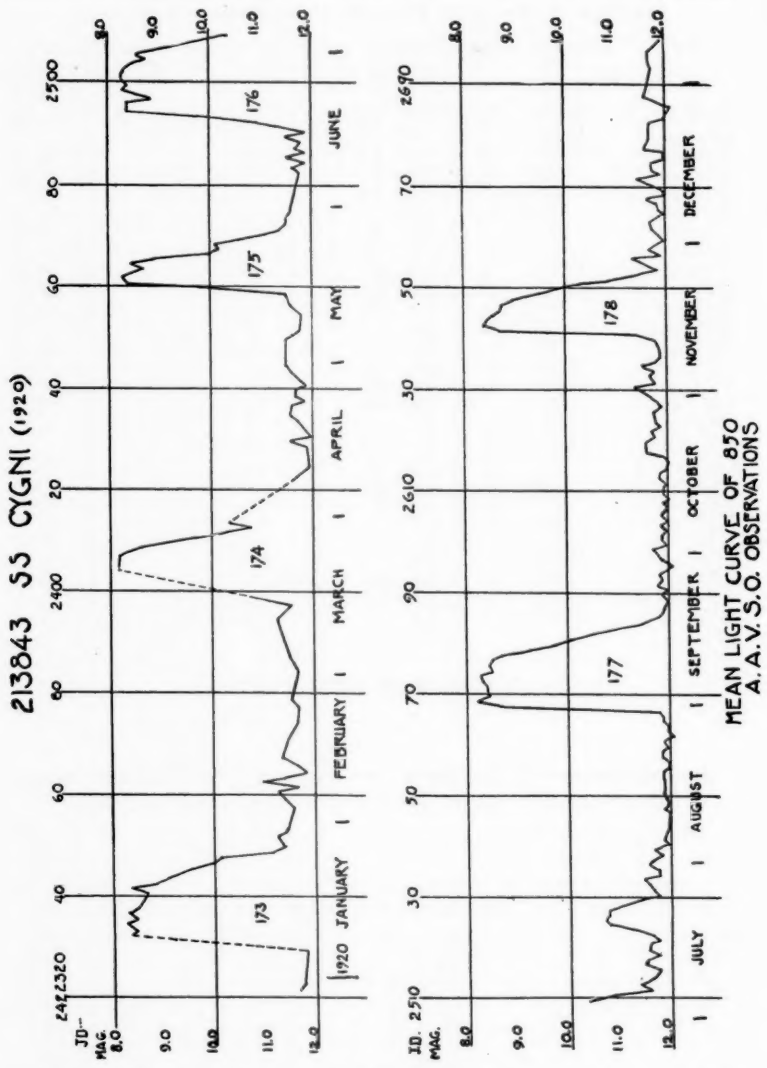
## NOTES FOR OBSERVERS.

### Monthly Report of the American Association of Variable Star Observers, December 20, 1920 to January 20, 1921.

The reports continue to show a great deal of work in progress on the part of the Association this winter; this month there is chalked up to our credit over three times the number of observations made in the corresponding month last year, and the last four months show a lead of 2,000 over the same period a year ago. To make some of the results of our work tangible, there is appended herewith a curve of the daily means of 850 A. A. V. S. O. observations of SS Cygni, 213843. The details of the maxima are as follows:

| No. Max. | Mag. Max. | Type | J. D. 10.0 i | Δ | J. D. Max. | Δ | J. D. 10.0 d | Δ |
|---|---|---|---|---|---|---|---|---|
| 173 | 8.4 | Long | 2422331 | 71 | 2337 | 68 | 2346 | 65 |
| 174 | 8.2 | Short | 2402 | 57 | 2405 | 57 | 2411 | 56 |
| 175 | 8.3 | Short | 2459 | 34 | 2462 | 38 | 2467 | 41 |
| 176 | 8.3 | Long | 2493 | 74 | 2500 | 26 | 2508 | 72 |
| ... | 10.6 | Anom. | .... | .. | 2526 | 46 | .... | .. |
| 177 | 8.4 | Long | 2567 | 74 | 2572 | 72 | 2580 | 70 |
| 178 | 8.4 | Short | 2641 | .. | 2644 | .. | 2650 | .. |

Observations of this star at this time of the year are particularly valuable. Mr. K. Reesinck and Miss Hawes send their first lists of observations this month.




and Messrs Chandra, Ginori, and Peltier are to be commended for excellent reports. The lists of Messrs. Furukawa and Yamamoto were badly scorched in some fire in transit, but fortunately were not destroyed.

The Association is very greatly indebted to Mr. D. B. Pickering for the liberal supply of report blanks which have been sent out to all observers. Those failing to receive their packets should notify the recording secretary. These

VARIABLE STAR OBSERVATIONS, December 20, 1920 to January 20, 1921.
December 0 = 2422659 January 0 = 2422690

| Number | Name | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *001032* | S Sculptoris | 2699.5 | 6.5 | Pt. | | | | | | | | | |
| 001046 | X Androm. | 2690.6 | 9.3 | Hu, | 2707.5 | 11.6 | Pi. | | | | | | |
| 001726 | T Androm. | 2635.1 | *11.0* | Ch. | | | | | | | | | |
| 001755 | T Cassiop. | 2642.4 | 8.2 | Gi, | 2661.5 | 8.2 | Gi, | 2662.5 | 7.3 | Mt, | 2671.3 | 7.3 | Mt, |
| | | 2680.4 | 7.9 | Mt, | 2699.5 | 8.1 | Mt, | 2707.5 | 8.6 | Pi. | | | |
| 001838 | R Androm. | 2635.1 | 9.4 | Ch, | 2641.4 | 9.4 | Ja, | 2645.0 | 9.0 | Ch, | 2659.3 | 8.9 | Ja, |
| | | 2660.4 | 9.1 | Pe, | 2662.5 | 8.5 | Mt, | 2664.4 | 9.0 | Ja, | 2671.3 | 8.5 | Mt, |
| | | 2672.3 | 9.1 | Ja, | 2679.5 | 8.5 | Ro, | 2680.4 | 8.1 | Mt, | 2684.5 | 8.3 | Ro, |
| | | 2684.6 | 8.8 | Jd, | 2689.6 | 8.5 | Pt, | 2690.6 | 8.0 | Hu, | 2695.5 | 8.1 | Ro, |
| | | 2707.5 | 8.8 | Pi, | 2709.5 | 9.3 | Jd. | | | | | | |
| *001909* | S Ceti | 2634.1 | *11.5* | Ch, | 2666.3 | *10.5* | Rk, | 2687.3 | *11.8* | Rk | | | |
| 004047 | U Cassiop. | 2661.5 | 12.3 | Hs, | 2689.6 | 11.6 | Pt, | 2696.6 | 11.1 | Y. | | | |
| 004435 | V Androm. | 2690.6 | 10.5 | Hu. | | | | | | | | | |
| 004958 | W Cassiop. | 2639.5 | 8.8 | Gi, | 2661.5 | 8.6 | Gi, | 2689.6 | 8.9 | Pt, | 2690.6 | 8.0 | Hu, |
| | | 2692.5 | 9.0 | Gd, | 2698.6 | 8.8 | B. | | | | | | |
| 011208 | S Piscium | 2698.7 | *13.0* | Y. | | | | | | | | | |
| 011272 | S Cassiop. | 2661.5 | 12.2 | Hs. | | | | | | | | | |
| 012350 | RZ Persei | 2696.6 | 11.6 | Y. | | | | | | | | | |
| 012502 | R Piscium | 2661.3 | 11.4 | Rk, | 2666.3 | 11.6 | Rk, | 2698.6 | *13.1* | Y. | | | |
| 013238 | RU Androm. | 2633.1 | *11.0* | Ch, | 2645.0 | 11.0 | Ch, | 2689.7 | 10.1 | Pt, | 2701.6 | 10.6 | B. |
| 013338 | Y Androm. | 2633.1 | *11.0* | Ch. | | | | | | | | | |
| 014958 | X Cassiop. | 2689.7 | 11.0 | Pt, | 2696.6 | 10.5 | Y. | | | | | | |
| 015354 | U Persei | 2679.8 | 11.2 | Pw, | 2689.7 | 9.8 | Pt, | 2690.6 | 9.5 | Hu, | 2693.6 | 11.0 | Hl. |
| 021024 | R Arietis | 2634.5 | 8.9 | Gi, | 2647.4 | 9.0 | Gi, | 2666.4 | 9.9 | Gi. | 2689.6 | 12.4 | Pt. |
| 021143 | W Androm. | 2643.4 | 10.4 | Gi, | 2662.5 | 11.2 | Gi. | | | | | | |
| *021403* | o Ceti | 2634.1 | 8.1 | Ch, | 2685.3 | 9.0 | L, | 2687.5 | 8.9 | Pt, | 2690.6 | 9.5 | Ya, |
| | | 2692.5 | 9.3 | Sz, | 2692.6 | 9.2 | Hu, | 2694.7 | 8.4 | Bs, | 2695.5 | 9.2 | Sz, |
| | | 2697.7 | 8.6 | Bs, | 2698.5 | 9.2 | Sz, | 2698.7 | 8.8 | Bs, | 2702.5 | 9.4 | Sz. |
| 022150 | RR Persei | 2696.6 | 10.2 | Y. | | | | | | | | | |
| *022813* | U Ceti | 2634.1 | 8.3 | Ch, | 2644.2 | 7.8 | Ch, | 2673.6 | 7.3 | Pw, | 2686.7 | 7.5 | Ml, |
| | | 2689.5 | 7.7 | Pt, | 2692.6 | 8.3 | Ya, | 2692.6 | 7.8 | Hu, | 2698.6 | 8.3 | Y. |
| 023133 | R Trianguli | 2686.6 | 11.1 | Ml, | 2689.7 | 11.2 | Pt, | 2692.6 | 11.1 | Ya, | 2692.6 | 10.3 | Hu. |
| 024356 | W Persei | 2677.6 | 9.9 | Cl, | 2687.5 | 9.8 | Pt, | 2690.6 | 9.0 | Hu, | 2692.5 | 9.2 | Gd, |
| | | 2692.6 | 9.4 | Ya. | | | | | | | | | |
| 030514 | U Arietis | 2642.4 | *13.8* | Gi, | 2662.5 | *13.8* | Gi, | 2698.6 | *13.5* | Y. | | | |
| *031401* | X Ceti | 2689.6 | 10.4 | Pt. | | | | | | | | | |
| 032043 | Y Persei | 2689.5 | 8.4 | Pt, | 2690.6 | 8.2 | Hu, | 2693.5 | 8.9 | Ya. | | | |
| 032335 | R Persei | 2634.5 | 10.6 | Gi, | 2647.4 | 9.5 | Gi, | 2666.5 | 8.9 | Gi, | 2689.5 | 8.6 | Pt, |
| | | 2690.6 | 8.3 | Hu, | 2692.6 | 8.4 | Ya. | | | | | | |
| 033362 | U Camelop. | 2693.6 | 8.2 | Ya. | | | | | | | | | |
| *034625* | U Eridani | 2676.6 | *11.0* | Pw. | | | | | | | | | |
| *035124* | T Eridani | 2686.6 | 8.5 | Ml. | | | | | | | | | |
| 042209 | R Tauri | 2689.6 | 10.4 | Pt, | 2692.6 | 10.0 | Hu, | 2693.6 | 12.0 | Hl, | 2706.5 | 11.0 | Ya. |
| 042215 | W Tauri | 2660.4 | 11.8 | Pe, | 2669.3 | 9.7 | Ja, | 2677.5 | 10.8 | Cl, | 2689.6 | 11.9 | Pt, |
| | | 2692.5 | *11.4* | Sz, | 2699.6 | 11.2 | M, | 2703.6 | 9.8 | B. | | | |
| 042309 | S Tauri | 2693.6 | 14.1 | Hl. | | | | | | | | | |
| 043065 | T Camelop. | 2693.6 | 13.8 | Hl. | | | | | | | | | |
| 043274 | X Camelop. | 2693.5 | 10.4 | Pt, | 2702.6 | 11.0 | Y. | | | | | | |
| 045307 | R Orionis | 2642.5 | 11.5 | Gi, | 2662.5 | 11.9 | Gi, | 2698.6 | 12.6 | Y. | | | |

VARIABLE STAR OBSERVATIONS, December 20, 1920 to January 20, 1921—Continued

| Number | Name | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *045514* | R Leporis | 2631.2 | 9.8 | Ch, | 2635.3 | 8.6 | L, | 2673.3 | 8.9 | Rk, | 2673.6 | 7.7 | Pw, |
| | | 2675.7 | 9.7 | Sz, | 2686.7 | 8.2 | E, | 2686.7 | 9.0 | H, | 2686.7 | 9.0 | Jo, |
| | | 2689.6 | 8.8 | Pt, | 2694.6 | 9.0 | Ya. | | | | | | |
| 050003 | U Orionis | 2698.6 | 12.7 | Y. | | | | | | | | | |
| *050022* | T Leporis | 2689.6 | 9.2 | Pt, | 2696.6 | 9.0 | Ya. | | | | | | |
| 050953 | R Aurigae | 2693.6 | 13.9 | Hl, | 2694.6 | *11.1* | Ya, | 2698.8 | 12.4 | M. | | | |
| 052034 | S Aurigae | 2690.6 | 8.6 | Pw, | 2692.8 | 10.3 | M, | 2693.6 | 8.7 | Hl, | 2693.6 | 9.3 | Ya. |
| 052036 | W Aurigae | 2634.5 | 9.3 | Gi, | 2647.4 | 9.6 | Gi, | 2667.4 | 10.3 | Gi, | 2679.6 | *10.6* | Jd, |
| | | 2689.5 | 11.7 | Pt, | 2692.8 | 12.0 | M. | | | | | | |
| *053005a* | T Orionis | 2660.4 | 10.4 | Pe, | 2667.5 | 9.8 | L, | 2672.4 | 9.9 | L, | 2685.3 | 10.1 | L, |
| | | 2688.5 | 10.5 | Pt, | 2692.5 | 9.7 | Gd, | 2696.5 | 9.8 | B, | 2706.6 | 11.0 | Ya. |
| 053068 | S Camelop. | 2693.5 | 8.6 | Pt, | 2693.6 | 8.6 | Ya. | | | | | | |
| 053326 | RR Tauri | 2669.3 | 12.3 | Ja, | 2671.4 | 11.8 | Ja, | 2673.4 | 12.0 | Ja, | 2677.5 | 10.7 | Cl, |
| | | 2694.0 | 11.2 | Ka, | 2696.5 | 10.7 | B, | 2699.6 | 11.0 | M, | 2701.5 | 10.9 | Cl. |
| 053531 | U Aurigae | 2693.6 | 11.1 | Ya, | 2693.6 | 13.7 | Hl, | 2702.6 | *12.8* | Y. | | | |
| 054319 | SU Tauri | 2631.2 | 9.2 | Ym, | 2631.2 | 9.7 | Ch, | 2635.0 | 9.2 | Ym, | 2638.2 | 9.2 | Ch. |
| | | 2641.0 | 9.2 | Ym, | 2643.0 | 9.4 | Ym, | 2645.2 | 9.5 | Ch, | 2667.6 | 9.6 | L, |
| | | 2677.6 | 9.0 | Cl, | 2678.5 | 9.4 | Pt, | 2679.5 | 9.4 | Cl, | 2685.3 | 9.4 | L, |
| | | 2688.5 | 9.4 | Pt, | 2689.6 | 9.5 | Pt, | 2691.8 | 9.6 | Pt, | 2692.6 | 9.5 | Hu, |
| | | 2693.5 | 9.5 | Pt, | 2696.5 | 9.5 | B, | 2698.6 | 9.5 | Y, | 2698.6 | 9.6 | Pt, |
| | | 2698.8 | 9.9 | M, | 2701.5 | 9.1 | Cl, | 2701.6 | 9.5 | B, | 2701.7 | 9.5 | Pt, |
| | | 2706.5 | 9.4 | Cl, | 2707.5 | 9.5 | Pt. | | | | | | |
| 054615a | Z Tauri | 2698.7 | 11.8 | Y. | | | | | | | | | |
| 054615b | RS Tauri | 2698.7 | 9.2 | Y. | | | | | | | | | |
| 054920 | U Orionis | 2631.2 | 8.7 | Ch, | 2679.6 | 8.5 | Pw, | 2687.6 | 9.1 | Pw, | 2689.6 | 10.2 | Pt, |
| | | 2691.7 | 10.8 | Mu, | 2692.6 | 10.5 | Hu, | 2693.6 | 10.3 | Su, | 2695.5 | 10.1 | Sz, |
| | | 2696.5 | 9.9 | B, | 2696.6 | 10.4 | Ya, | 2698.8 | 10.5 | M, | 2702.5 | 10.6 | Sz. |
| 054974 | V Camelop. | 2643.4 | *13.8* | Gi, | 2683.4 | *12.8* | Gi, | 2698.8 | *12.2* | M, | 2702.6 | *13.0* | Y. |
| 055353 | Z Aurigae | 2661.5 | 11.1 | Hs, | 2692.8 | 10.0 | M, | 2693.6 | 9.6 | Ya, | 2694.6 | 10.4 | Ka. |
| 060450 | X Aurigae | 2679.5 | 10.4 | Ro, | 2689.6 | 10.0 | Pt, | 2695.5 | 11.0 | Ro, | 2696.6 | 11.5 | B, |
| | | 2698.8 | 11.6 | M. | | | | | | | | | |
| 060547 | SS Aurigae | 2631.0 | *14.0* | Ym, | 2632.2 | *11.6* | Ch, | 2634.4 | *13.8* | Gi, | 2635.0 | *14.0* | Ym, |
| | | 2636.5 | *13.8* | Gi, | 2639.5 | *13.8* | Gi, | 2640.4 | *13.8* | Gi, | 2641.1 | *13.9* | Ym. |
| | | 2641.4 | *12.4* | Ja, | 2641.4 | *13.9* | Gi, | 2642.5 | *13.9* | Gi, | 2643.0 | *13.9* | Ym, |
| | | 2643.4 | *13.9* | Gi, | 2644.4 | *13.9* | Gi, | 2645.0 | *13.5* | Ym, | 2645.2 | *14.0* | Ym, |
| | | 2645.6 | *13.8* | Gi, | 2647.4 | *13.8* | Gi, | 2647.5 | *12.4* | Ja, | 2648.4 | *13.8* | Gi, |
| | | 2653.4 | *12.4* | Gi, | 2660.5 | *13.3* | Ja, | 2661.3 | 13.3 | Rk, | 2661.6 | *13.8* | Gi, |
| | | 2662.5 | *13.8* | Gi, | 2664.4 | 12.0 | Ja, | 2665.3 | 11.0 | Ja, | 2666.3 | 11.3 | Rk, |
| | | 2666.5 | 11.0 | Gi, | 2667.4 | 10.9 | Gi, | 2667.6 | 10.9 | L, | 2668.3 | 10.8 | Ja, |
| | | 2669.4 | 10.7 | Ja, | 2670.3 | 10.7 | Ja, | 2671.3 | 10.7 | L, | 2671.4 | 10.8 | Ja, |
| | | 2672.3 | 10.8 | Ja, | 2672.4 | 10.9 | L, | 2673.3 | 12.9 | Rk, | 2673.4 | 11.7 | Ja. |
| | | 2676.3 | 13.3 | Gi, | 2676.4 | 12.6 | Ja, | 2677.6 | *12.4* | Cl, | 2678.9 | 13.5 | Pt, |
| | | 2679.5 | *11.6* | Cl, | 2679.5 | *11.0* | Jd, | 2683.4 | *13.3* | Gi, | 2682.7 | *12.4* | L. |
| | | 2685.2 | *11.5* | L, | 2687.5 | *12.4* | Pt, | 2688.5 | *12.6* | Pt, | 2689.5 | *12.6* | Pt. |
| | | 2691.8 | *12.6* | Pt, | 2692.5 | *12.6* | Pt, | 2692.8 | *12.4* | M, | 2693.5 | *13.0* | Pt, |
| | | 2694.6 | *12.6* | Pt, | 2696.5 | *14.0* | B, | 2698.6 | *12.6* | Pt, | 2699.5 | *13.0* | Pt, |
| | | 2700.5 | *13.0* | Pt, | 2701.5 | *12.4* | Cl, | 2702.6 | *13.3* | Y, | 2702.6 | *12.6* | Pt. |
| | | 2706.5 | *12.4* | Cl, | 2706.6 | *11.4* | Ya, | 2707.5 | *12.6* | Pt, | 2707.5 | *12.4* | Y. |
| 061647 | V Aurigae | 2696.6 | 10.0 | B. | | | | | | | | | |
| 063159 | U Lyncis | 2702.6 | *12.8* | Y. | | | | | | | | | |
| 063558 | S Lyncis | 2689.6 | 9.8 | Pt, | 2706.6 | 11.2 | Ya. | | | | | | |
| 064030 | X Gemin. | 2642.5 | 9.1 | Gi, | 2672.3 | 9.7 | Ja. | | | | | | |
| *064707* | W Monoc. | 2689 7 | 11.0 | Pt. | | | | | | | | | |
| 065111 | Y Monoc. | 2696.6 | 11.0 | Ya, | 2698.7 | 11.0 | Y. | | | | | | |
| *065208* | X Monoc. | 2667.6 | 7.7 | L, | 2696.6 | 7.7 | Ya. | | | | | | |
| 065355 | R Lyncis | 2643.4 | 12.8 | Gi, | 2683.6 | *12.8* | Gi, | 2702.6 | *13.1* | Y. | | | |

VARIABLE STAR OBSERVATIONS, December 20, 1920 to January 20, 1921—Continued

| Number | Name | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 070122a | R Gemin. | 2632.2 | 7.3 | Ch, | 2641.2 | 7.5 | Ch, | 2650.2 | 7.6 | Ch, | 2686.7 | 7.9 | Ml, |
| | | 2689.7 | 8.7 | Pt, | 2692.6 | 8.0 | Hu, | 2709.6 | 8.3 | Jd. | | | |
| 070122b | Z Gemin. | 2632.2 | 11.5 | Ch, | 2641.2 | 10.9 | Ch, | 2689.7 | 12.5 | Pt. | | | |
| 070310 | R Canis Min. | 2667.6 | 8.7 | L, | 2685.3 | 8.6 | L, | 2687.7 | 8.6 | Ml. | | | |
| *071044* | $L_2$ Puppis | 2639.4 | 6.0 | Ch. | | | | | | | | | |
| 071713 | V Gemin. | 2689.7 | 9.5 | Pt. | | | | | | | | | |
| 072708 | S Canis Min. | 2633.2 | 10.0 | Ch, | 2660.4 | 10.5 | Pe, | 2690.6 | *11.0* | Pw, | | | |
| | | 2693.6 | 12.7 | Su, | 2694.8 | 10.2 | Bs, | 2697.8 | 10.4 | Bs, | 2702.7 | 10.2 | Bs. |
| 073508 | U Canis Min. | 2689.7 | 10 8 | Pt, | 2698.7 | 10.9 | Y, | 2700.6 | 11.5 | Hl. | | | |
| 074922 | U Gemin. | 2634.6 | *13.7* | Gi, | 2636.5 | 13.9 | Gi, | 2637.4 | *12.3* | Ch, | 2639.5 | *13.7* | Gi, |
| | | 2641.4 | *13.7* | Gi, | 2642.5 | *13.7* | Gi, | 2643.4 | *13.7* | Gi, | 2644.4 | *13.7* | Gi, |
| | | 2645.2 | 14.1 | Ym, | 2645.6 | *13.7* | Gi, | 2647.4 | *13.7* | Gi, | 2648.4 | *13.7* | Gi, |
| | | 2661.3 | *11.0* | Rk, | 2661.6 | 13.9 | Gi, | 2662.5 | 14.0 | Gi, | 2665.4 | *12.3* | Ja, |
| | | 2666.5 | *13.7* | Gi, | 2667.6 | *13.7* | L, | 2668.5 | *13.7* | Ja, | 2669.3 | *13.7* | Ja, |
| | | 2672.3 | *12.8* | Ja, | 2678.9 | *13.3* | Pt, | 2682.7 | 9.7 | L, | 2683.5 | 10.4 | Gi, |
| | | 2689.6 | *12.4* | Pt, | 2691.8 | *13.3* | Pt, | 2691.8 | 14.0 | Ka, | 2692.5 | *13.3* | Pt, |
| | | 2692.8 | *12.4* | M, | 2693.8 | 14.1 | Ka, | 2694.6 | *13.3* | Pt, | 2696.6 | 14.0 | B, |
| | | 2696.6 | *13.7* | Y, | 2698.6 | *13.3* | Pt, | 2698.7 | *13.3* | Y, | 2699.6 | *13.3* | Pt. |
| | | 2700.5 | *13.3* | Pt, | 2701.7 | *13.7* | Pt, | 2702.6 | *13.7* | Pt, | 2702.6 | *13.3* | Y. |
| | | 2707.5 | *12.4* | Y, | 2707.8 | *13.3* | Pt. | | | | | | |
| 081112 | R Cancri | 2637.4 | *10.2* | Ch, | 2689.7 | 10.0 | Pt. | | | | | | |
| 081617 | V Cancri | 2645.6 | 11.3 | Gi, | 2664.5 | 12.1 | Ja, | 2683.5 | 13.0 | Gi. | | | |
| 084803 | S Hydrae | 2637.4 | 7.5 | Ch, | 2651.4 | 7.6 | Ch, | 2686.8 | 8.9 | Ml, | 2689.7 | 9.3 | Pt, |
| | | 2695.6 | 9.2 | Sz. | | | | | | | | | |
| *085008* | T Hydrae | 2637.4 | 9.2 | Ch, | 2691.8 | 11.5 | Pt. | | | | | | |
| 085120 | T Cancri | 2682.7 | 9.4 | L, | 2693.6 | 9.4 | Pt. | | | | | | |
| 090151 | V Ursae Maj. | 2660.4 | 10.4 | Pe. | | | | | | | | | |
| 090425 | W Cancri | 2667.6 | 8.2 | L. | | | | | | | | | |
| *093014* | X Hydrae | 2698.6 | 9.4 | Pt. | | | | | | | | | |
| 093178 | Y Draconis | 2671.7 | 9.9 | Ka, | 2702.6 | 11.0 | Y. | | | | | | |
| 093934 | R Leo. Min. | 2637.4 | 10.5 | Ch, | 2678.9 | 11.8 | Ka, | 2689.7 | 10.9 | Pt, | 2691.8 | 10.8 | Ka, |
| | | 2693.8 | 10.7 | Ka. | | | | | | | | | |
| 094211 | R Leonis | 2637.4 | 8.6 | Ch, | 2652.4 | 8.4 | Ch, | 2689.7 | 5.6 | Pt, | 2692.9 | 6.0 | M, |
| | | 2693.7 | 6.2 | Su, | 2699.7 | 6.3 | Ga. | | | | | | |
| *094622* | Y Hydrae | 2707.9 | 7.1 | Pt. | | | | | | | | | |
| 095421 | V Leonis | 2707.9 | 11.5 | Pt. | | | | | | | | | |
| 103769 | R Urs. Maj. | 2639.4 | 8.3 | Ch, | 2652.4 | 7.7 | Ch, | 2675.6 | 8.0 | Ga, | 2689.7 | 8.6 | Pt, |
| | | 2692.8 | 9.8 | M, | 2695.6 | *8.2* | Ga, | 2700.7 | 8.4 | Bs. | | | |
| *104620* | V Hydrae | 2637.4 | 7.6 | Ch, | 2694.0 | 8.1 | Ka, | 2707.9 | 7.4 | Pt. | | | |
| 104814 | W Leonis | 2698.8 | 9.6 | Pt. | | | | | | | | | |
| 120012 | SU Virginis | 2664.6 | 11.8 | Ja, | 2668.6 | 11.3 | Ja, | 2676.7 | 10.5 | Ja, | 2683.6 | 10.0 | Ja. |
| *121418* | R Corvi | 2698.8 | 13.5 | Pt. | | | | | | | | | |
| 122001 | SS Virginis | 2682.7 | 5.9 | L. | | | | | | | | | |
| 122532 | T Can. Ven. | 2678.9 | 11.0 | Pt, | 2692.8 | 10.1 | M. | | | | | | |
| 123160 | T Urs. Maj. | 2639.4 | *11.0* | Ch, | 2678.9 | *12.0* | Ka, | 2695.7 | *10.8* | Sz, | 2698.8 | 12.8 | M, |
| | | 2700.7 | *11.5* | Bs. | | | | | | | | | |
| 123307 | R Virginis | 2682.7 | 10.4 | L, | 2678.9 | 9.9 | Pt, | 2686.9 | 10.1 | Ml. | | | |
| 123459 | RS Urs. Maj. | 2639.4 | 10.8 | Ch, | 2651.4 | 9.3 | Ch, | 2678.9 | 9.1 | Pt, | 2679.0 | 9.1 | Ka, |
| | | 2692.8 | 9.8 | M, | 2695.7 | 9.8 | Sz, | 2700.7 | 8.8 | Bs. | | | |
| 123961 | S Urs. Maj. | 2639.4 | 8.5 | Ch, | 2651.4 | 8.4 | Ch, | 2678.9 | 7.6 | Pt, | 2679.0 | 8.2 | Ka, |
| | | 2686.9 | 8.6 | Ml, | 2692.8 | 8.6 | M, | 2695.7 | 8.3 | Sz, | 2700.7 | 8.6 | Bs. |
| 124606 | U Virginis | 2678.9 | 9.5 | Pt. | | | | | | | | | |
| *132422* | R Hydrae | 2643.5 | 5.0 | Ch, | 2651.5 | 4.4 | Ch, | 2678.9 | 5.8 | Pt, | 2683.7 | 5.2 | Gi. |

VARIABLE STAR OBSERVATIONS, December 20, 1920 to January 20, 1921—Continued

| Number | Name | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 132706 | S Virginis | 2698.8 | 8.7 | Pt. | | | | | | | | | |
| 134440 | R Can. Ven. | 2678.9 | 11.6 | Pt, | 2692.8 | 11.4 | M. | | | | | | |
| *135908* | RR Virginis | 2698.8 | 12.6 | Pt. | | | | | | | | | |
| *140512* | Z Virginis | 2698.8 | 12.4 | Pt. | | | | | | | | | |
| 141567 | U Urs. Min. | 2643.5 | 11.5 | Ch, | 2678.9 | 12.0 | Pt. | | | | | | |
| 141954 | S Bootis | 2643.5 | 10.6 | Ch, | 2645.2 | 10.5 | Gi, | 2671.2 | 9.7 | Mt, | 2691.8 | 9.0 | Pt, |
| | | 2692.9 | 8.7 | M. | | | | | | | | | |
| 142539 | V Bootis | 2691.8 | 8.6 | Pt, | 2692.9 | 8.9 | M. | | | | | | |
| 142584 | R Camelop. | 2643.3 | 8.6 | Gi, | 2662.5 | 8.3 | Mt, | 2671.3 | 8.3 | Mt, | 2680.4 | 8.4 | Mt, |
| | | 2683.6 | 8.4 | Gi. | | | | | | | | | |
| 143227 | R Bootis | 2651.5 | 9.0 | Ch, | 2678.9 | 10.8 | Pt, | 2692.9 | 11.0 | M. | | | |
| 151731 | S Cor. Bor. | 2678.9 | 7.2 | Pt. | | | | | | | | | |
| 153378 | S Urs. Min. | 2630.9 | 8.6 | Ym, | 2643.0 | 9.0 | Ym, | 2655.9 | 9.4 | Ym, | | | |
| | | 2671.7 | 10.3 | Ka, | 2679.5 | 9.4 | Ro, | 2680.5 | 9.6 | Jd, | 2682.5 | 9.8 | Jd, |
| | | 2684.5 | 9.7 | Ro, | 2688.6 | 9.6 | Pt, | 2695.5 | 10.4 | Ro, | 2703.7 | 8.2 | Bs. |
| 154428 | R Cor. Bor. | 2628.0 | 6.3 | Ch, | 2634.2 | 6.2 | Gi, | 2635.0 | 6.1 | Ch, | 2644.2 | 6.2 | Gi, |
| | | 2678.9 | 6.0 | Pt, | 2692.9 | 6.4 | M, | 2698.8 | 6.1 | Pt, | 2707.8 | 6.0 | Pt. |
| 154615 | R Serpentis | 2707.9 | 11.0 | Pt. | | | | | | | | | |
| 154639 | V Cor. Bor. | 2678.9 | 7.6 | Pt. | | | | | | | | | |
| 162119 | U Herculis | 2628.0 | 9.3 | Ch, | 2643.3 | 7.9 | Gi, | 2645.0 | 8.2 | Ch, | 2678.9 | 7.3 | Pt. |
| 163137 | W Herculis | 2628.1 | 8.5 | Ch, | 2636.0 | 8.7 | Ch, | 2647.2 | 8.9 | Ja, | 2656.3 | 9.0 | Ja, |
| | | 2668.2 | 9.8 | Ja, | 2678.9 | 10.3 | Pt. | | | | | | |
| 163266 | R Draconis | 2635.0 | 9.3 | Ch, | 2653.0 | 8.6 | Ch, | 2678.9 | 8.4 | Pt, | 2707.5 | 9.2 | Y. |
| 164715 | S Herculis | 2643.2 | 11.8 | Gi. | | | | | | | | | |
| 171401 | Z Ophiuchi | 2643.2 | 10.4 | Gi, | 2698.9 | 8.9 | Pt. | | | | | | |
| 171723 | RS Herculis | 2698.9 | 9.5 | Pt. | | | | | | | | | |
| 172809 | RU Ophiuchi | 2698.9 | 12.6 | Pt. | | | | | | | | | |
| 175458a | T Draconis | 2641.3 | 12.4 | Gi, | 2683.2 | 12.2 | Gi. | | | | | | |
| 175519 | RU Herculis | 2632.1 | 9.3 | Ch, | 2638.1 | 9.2 | Ch, | 2645.0 | 9.3 | Ch, | 2698.9 | 12.2 | Pt. |
| 180531 | T Herculis | 2632.1 | *11.5* | Ch, | 2689.9 | 8.1 | Pt. | | | | | | |
| 180565 | W Draconis | 2678.9 | 10.5 | Pt. | | | | | | | | | |
| 180911 | Nova Ophiu. 4 | 2644.2 | 11.3 | Gi. | | | | | | | | | |
| 181031 | TV Herculis | 2685.2 | *12.0* | L. | | | | | | | | | |
| 181103 | RY Ophiuchi | 2642.2 | 8.4 | Gi, | 2667.2 | 10.1 | Gi. | | | | | | |
| 181136 | W Lyrae | 2689.5 | 8.7 | Pt, | 2698.5 | 8.7 | Su. | | | | | | |
| 182224 | SV Herculis | 2707.9 | 10.0 | Pt. | | | | | | | | | |
| 183149 | SV Draconis | 2707.5 | 12.0 | Y. | | | | | | | | | |
| *184205* | R Scuti | 2628.1 | 5.0 | Ch, | 2632.1 | 4.9 | Ch, | 2634.2 | 5.2 | Gi, | 2641.0 | 5.8 | Ch, |
| | | 2642.2 | 5.5 | Gi, | 2656.2 | 5.9 | Ja, | 2660.5 | 6.4 | Ms. | | | |
| 184300 | Nova Aquil. 3 | 2641.2 | 8.9 | Ja, | 2642.9 | 8.4 | Ym, | 2644.2 | 9.1 | Gi, | 2645.0 | 8.5 | Ch, |
| | | 2657.2 | 8.8 | Ja, | 2657.9 | 8.3 | Ym. | | | | | | |
| 184929 | Nova Lyrae 1 | 2634.4 | 12.8 | Gi, | 2647.2 | 12.6 | Gi. | | | | | | |
| 190925 | S Lyrae | 2685.2 | *11.6* | L. | | | | | | | | | |
| *191319* | S Sagittarii | 2639.2 | *13.2* | Gi. | | | | | | | | | |
| *191321* | Z Sagittarii | 2643.3 | 11.8 | Gi. | | | | | | | | | |
| 191350 | TZ Cygni | 2707.5 | 11.0 | Y. | | | | | | | | | |
| 191637 | U Lyrae | 2689.5 | 11.9 | Pt. | | | | | | | | | |
| 192928 | TY Cygni | 2688.5 | 9.6 | Pt. | | | | | | | | | |
| 193449 | R Cygni | 2632.1 | *11.5* | Ch, | 2659.5 | 10.4 | Hs, | 2661.5 | 9.7 | Hs, | 2677.5 | 9.9 | Sz, |
| | | 2687.5 | 9.0 | Pt, | 2691.7 | 9.0 | Bs, | 2692.5 | 9.5 | Sz, | 2695.5 | 9.4 | Sz, |
| | | 2698.5 | 9.3 | Sz, | 2698.8 | 8.8 | Bs, | 2702.5 | 8.8 | Sz. | | | |

VARIABLE STAR OBSERVATIONS, December 20, 1920 to January 20, 1921—Continued

| Number | Name | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 194048 | RT Cygni | 2632.1 | *11.5* | Ch, | 2634.4 | 11.3 | Gi, | 2644.1 | 11.0 | Ch, | 2647.3 | 9.7 | Gi, |
| | | 2648.1 | 10.6 | Ch, | 2672.3 | 8.7 | Gi, | 2682.5 | 8.0 | Jd, | 2683.2 | 7.9 | Gi, |
| | | 2684.5 | 8.0 | Jd, | 2687.5 | 7.3 | Pt, | 2691.7 | 10.2 | Bs, | 2692.5 | 7.3 | Sz, |
| | | 2693.5 | 8.3 | Jd, | 2695.5 | 7.3 | Sz, | 2698.5 | 7.2 | Sz, | 2698.8 | 10.0 | Bs, |
| | | 2702.5 | 7.1 | Sz. | | | | | | | | | |
| 194632 | χ Cygni | 2631.0 | 9.9 | Ym, | 2632.2 | 9.9 | Ch, | 2641.2 | 10.7 | Ja, | 2645.1 | 10.0 | Ym, |
| | | 2657.2 | 11.3 | Ja, | 2657.9 | 12.2 | Ym, | 2660.3 | 11.1 | Rk, | 2666.3 | 11.5 | Rk, |
| | | 2668.3 | 11.9 | Ja, | 2671.2 | 11.7 | Mt, | 2680.4 | 11.9 | Mt. | | | |
| 195116 | S Sagittae | 2685.6 | 5.6 | Mu, | 2686.6 | 5.5 | Mu, | 2689.6 | 5.3 | Mu, | 2695.6 | 5.3 | Mu, |
| | | 2696.6 | 5.4 | Mu, | 2698.6 | 5.6 | Mu. | | | | | | |
| 195553 | Nova Cygni 3 | 2569.0 | 4.3 | Fk, | 2569.9 | 4.2 | Fk, | 2570.2 | 4.2 | Fk, | 2570.9 | 4.4 | Fk, |
| | | 2571.2 | 4.3 | Fk, | 2572.1 | 4.4 | Fk, | 2573.0 | 4.5 | Fk, | 2573.9 | 4.5 | Fk, |
| | | 2575.0 | 4.5 | Fk, | 2577.0 | 4.7 | Fk, | 2578.9 | 5.1 | Fk, | 2580.0 | 5.3 | Fk, |
| | | 2580.9 | 5.6 | Fk, | 2584.1 | 5.6 | Fk, | 2585.2 | 5.9 | Fk, | 2586.1 | 6.1 | Fk, |
| | | 2618.6 | 8.6 | Hw, | 2631.0 | 8.7 | Ym, | 2634.0 | 9.2 | Ym, | 2634.4 | 9.7 | Gi, |
| | | 2636.4 | 9.8 | Gi, | 2637.0 | 8.7 | Ym, | 2639.4 | 9.8 | Gi, | 2641.1 | 9.3 | Ym, |
| | | 2641.3 | 9.8 | Gi, | 2642.0 | 9.6 | Ym, | 2642.4 | 9.9 | Gi, | 2643.1 | 9.4 | Ym, |
| | | 2644.4 | 9.9 | Gi, | 2645.1 | 9.4 | Ym, | 2647.3 | 9.4 | Gi, | 2648.0 | 8.1 | Ym, |
| | | 2648.3 | 9.7 | Gi, | 2650.3 | 9.5 | Gi, | 2652.9 | 9.1 | Ym, | 2654.3 | 9.6 | Gi, |
| | | 2655.9 | 8.6 | Ym, | 2656.9 | 8.5 | Ym, | 2657.9 | 8.8 | Ym, | 2661.3 | 9.5 | Gi, |
| | | 2662.5 | 9.1 | Mt, | 2666.6 | 8.6 | Hw, | 2671.3 | 9.3 | Mt, | 2671.7 | 8.6 | Ka, |
| | | 2672.4 | 8.8 | L, | 2677.6 | 9.2 | Cl, | 2679.5 | 8.7 | Pt, | 2679.5 | 8.6 | Ro, |
| | | 2680.4 | 9.4 | Mt, | 2683.3 | 9.7 | Gi, | 2684.5 | 8.6 | Ro, | 2685.2 | 8.7 | L, |
| | | 2685.6 | 8.6 | Ka, | 2687.5 | 8.8 | Pt, | 2688.5 | 8.6 | Pt, | 2689.5 | 8.7 | Pt, |
| | | 2692.5 | 8.7 | Pt, | 2692.5 | 8.7 | Gd, | 2693.5 | 8.7 | Pt, | 2693.5 | 9.2 | Jd, |
| | | 2693.7 | 8.7 | Ka, | 2694.6 | 8.6 | Pt, | 2695.5 | 8.8 | Ro, | 2698.6 | 8.7 | Pt, |
| | | 2700.5 | 8.6 | Pt, | 2700.7 | 8.6 | Ka, | 2702.6 | 8.6 | Pt, | 2707.5 | 9.0 | Pt. |
| 195849 | Z Cygni | 2634.4 | 12.5 | Gi, | 2647.3 | 11.5 | Gi, | 2659.5 | 10.1 | Hs, | 2661.5 | 9.7 | Hs, |
| | | 2683.3 | 8.7 | Gi, | 2688.5 | 9.0 | Pt. | | | | | | |
| 200212 | SY Aquilae | 2685.2 | 11.8 | L. | | | | | | | | | |
| *200514* | R Capricorni | 2636.3 | 12.7 | Gi. | | | | | | | | | |
| 200715a | S Aquilae | 2634.3 | 9.6 | Gi, | 2647.2 | 10.2 | Gi, | 2677.5 | 10.9 | Sz, | 2688.5 | 10.0 | Pt, |
| | | 2692.5 | 11.2 | Sz. | | | | | | | | | |
| 200715b | RW Aquilae | 2677.5 | 8.9 | Sz, | 2692.5 | 9.1 | Sz. | | | | | | |
| *200906* | Z Aquilae | 2644.3 | 10.9 | Gi, | 2672.3 | 11.3 | Gi. | | | | | | |
| 200916 | R Sagittae | 2677.5 | 8.8 | Sz, | 2692.5 | 8.8 | Sz. | | | | | | |
| 200938 | RS Cygni | 2631.2 | 7.1 | Ch, | 2643.2 | 7.3 | Ch, | 2682.5 | 7.8 | Gd, | 2688.5 | 7.3 | Pt, |
| | | 2699.5 | 8.2 | M. | | | | | | | | | |
| 201008 | R Delphini | 2688.5 | 8.6 | Pt. | | | | | | | | | |
| 201130 | SX Cygni | 2707.5 | 9.4 | Y. | | | | | | | | | |
| 201437a | P Cygni | 2631.2 | 5.2 | Ch. | | | | | | | | | |
| 201647 | U Cygni | 2636.4 | 8.5 | Gi, | 2648.3 | 8.0 | Gi, | 2659.5 | 8.1 | Hs, | 2661.5 | 8.0 | Hs, |
| | | 2677.5 | 7.7 | Sz, | 2679.5 | 7.4 | Ro, | 2683.5 | 6.8 | Jd, | 2683.3 | 7.7 | Gi, |
| | | 2684.5 | 7.3 | Ro, | 2688.5 | 7.4 | Pt, | 2692.5 | 7.7 | Sz, | 2695.5 | 7.0 | Ro, |
| | | 2695.5 | 7.6 | Sz, | 2696.5 | 7.4 | Jd, | 2698.5 | 7.6 | Sz, | 2699.5 | 7.6 | M, |
| | | 2702.5 | 7.6 | Sz, | 2709.4 | 7.2 | Jd. | | | | | | |
| 202539 | RW Cygni | 2699.5 | 8.6 | M. | | | | | | | | | |
| *202622* | RU Capricor. | 2637.3 | 13.2 | Gi. | | | | | | | | | |
| 202817 | Z Delphini | 2657.2 | *12.4* | Ja, | 2668.3 | 13.0 | Ja. | | | | | | |
| 202946 | SZ Cygni | 2679.5 | 9.6 | Cl. | | | | | | | | | |
| 202954 | ST Cygni | 2698.6 | 12.3 | Y. | | | | | | | | | |
| 203226 | V Vulpec. | 2688.5 | 9.7 | Pt. | | | | | | | | | |
| 203611 | Y Delphini | 2639.3 | 11.8 | Ja, | 2656.2 | 12.2 | Ja, | 2668.3 | 12.7 | Ja. | | | |

VARIABLE STAR OBSERVATIONS, December 20, 1920 to January 20, 1921—Continued

| Number | Name | J.D. Est. Obs. J.D. Est. Obs. J.D. Est. Obs. J.D. Est. Obs. |
|---|---|---|
| 203847 | V Cygni | 2633.2 *11.8* Ch, 2639.4 10.7 Gi, 2654.3 10.6 Gi, 2659.5 11.9 Hs, 2661.5 12.1 Hs, 2662.4 12.3 Mt, 2671.3 11.8 Mt, 2680.4 12.1 Mt, 2683.3 10.7 Gi, 2698.5 *12.0* M. |
| 204016 | T Delphini | 2689.5 11.9 Pt. |
| *204104* | W Aquarii | 2636.4 *13.5* Gi, 2655.9 *13.0* Ym, 2657.9 *13.0* Ym. |
| *204215* | U Capricorni | 2639.2 *13.9* Gi, 2667.2 12.8 Gi. |
| 204318 | V Delphini | 2636.4 *12.5* Gi, 2648.3 *12.5* Gi. |
| *204405* | T Aquarii | 2633.1 10.5 Ch. |
| 204846 | RZ Cygni | 2641.4 11.2 Gi, 2654.4 11.3 Gi, 2683.4 11.5 Gi. |
| 205923 | R Vulpec. | 2634.3 8.7 Gi, 2647.3 9.1 Gi, 2666.4 10.9 Gi. |
| *210124* | V Capricor. | 2639.3 *12.7* Gi. |
| 210129 | TW Cygni | 2707.5 11.1 Y. |
| *210221* | X Capricorni | 2639.3 11.0 Gi. |
| 210868 | T Cephei | 2633.1 9.5 Ch, 2687.5 7.5 Pt. |
| 211614 | X Pegasi | 2636.4 11.7 Gi, 2707.5 11.0 Y. |
| 213244 | W Cygni | 2662.4 6.5 Mt, 2671.3 6.2 Mt, 2680.4 6.9 Mt. |
| 213678 | S Cephei | 2639.5 10.0 Gi, 2661.5 9.8 Gi. |
| 213843 | SS Cygni | 2618.6 11.9 Hw, 2628.1 11.6 Ch, 2631.0 11.8 Ym, 2634.3 11.9 Gi, 2635.0 12.0 Ym, 2636.3 12.0 Gi, 2636.9 12.0 Ym, 2637.4 11.9 Gi, 2638.1 11.8 Ch, 2638.4 12.0 Gi, 2639.3 12.0 Ja, 2639.4 11.9 Gi, 2640.2 11.3 Ch, 2640.4 11.2 Gi, 2641.1 9.2 Ym, 2641.2 8.3 Ja, 2641.2 8.9 Ch, 2641.2 9.2 Ja, 2641.4 9.0 Ja, 2642.0 8.2 Ym, 2642.2 8.5 Ch, 6242.4 8.6 Gi, 2642.4 8.2 Ja, 2642.7 8.5 Hw, 2643.0 8.3 Ym, 2643.2 8.6 Ch, 2643.3 8.4 Ja, 2643.5 8.5 Hw, 2643.6 8.6 Hw, 2644.4 8.7 Gi, 2644.4 8.4 Ja, 2645.0 8.8 Ym, 2645.2 8.4 Ja, 2646.2 8.7 Ch, 2647.3 8.6 Ja, 2647.4 9.1 Gi, 2647.6 9.2 Hw, 2648.0 9.5 Ym, 2648.1 9.0 Ch, 2648.4 9.5 Gi, 2650.3 10.2 Gi, 2651.3 10.9 Ja, 2652.4 11.3 Ja, 2652.9 11.8 Ym, 2653.4 12.0 Gi, 2654.2 11.9 Ja, 2655.9 12.0 Ym, 2656.3 11.9 Ja, 2657.3 11.9 Ja, 2659.4 12.0 Ja, 2660.3 11.9 Rk, 2660.4 11.6 Pe, 2661.3 12.0 Gi, 2661.6 11.9 Hw, 2664.4 12.0 Ja, 2666.3 11.9 Rk, 2666.4 12.0 Gi, 2666.6 11.8 Hw, 2667.9 12.0 Ym, 2668.3 12.0 Ja, 2669.3 12.0 Ja, 2670.3 11.9 Ja, 2672.3 11.9 Ja, 2672.3 12.0 Gi, 2672.4 11.9 L, 2673.4 11.7 Ja, 2679.5 12.0 Ro, 2679.5 11.6 Pt, 2680.5 *10.8* Jd, 2682.4 12.1 Gd, 2682.5 *10.8* Jd, 2683.4 12.0 Gi, 2684.5 11.5 Jd, 2684.5 12.0 Ro, 2685.2 12.1 L, 2687.5 11.8 Pt, 2688.5 11.9 Pt, 2689.5 11.6 Pt, 2690.6 *11.3* Ya, 2692.5 11.9 Gd, 2692.5 11.9 Pt, 2693.5 11.8 Jd, 2693.5 11.9 Pt, 2694.6 11.8 Pt, 2695.5 12.0 Ro, 2696.5 11.8 B, 2696.6 12.0 Y, 2698.4 11.8 Jd, 2698.5 11.9 B, 2698.6 11.9 Pt, 2698.6 12.0 Y, 2699.5 11.6 M, 2699.5 11.8 Pt, 2700.5 11.8 Pt, 2701.5 11.9 B, 2701.7 11.8 Pt, 2702.6 11.6 Pt, 2703.6 11.9 B, 2706.5 *10.9* Cl, 2707.5 11.9 Pt, 2707.5 *11.8* Pi, 2707.5 12.0 Y. |
| 214024 | RR Pegasi | 2639.3 11.7 Ja, 2664.4 12.4 Ja. |
| 220412 | T Pegasi | 2636.4 *13.5* Gi, 2661.4 *13.5* Gi. |
| 220613 | Y Pegasi | 2641.4 *13.4* Gi. |
| 220714 | RS Pegasi | 2639.3 12.8 Gi. |
| 222129 | RV Pegasi | 2698.6 *12.7* B. |
| 222439 | S Lacertae | 2642.3 10.0 Gi, 2654.4 9.6 Gi, 2683.4 8.2 Gi, 2698.6 7.9 B, 2707.5 8.4 Pi. |
| 223841 | R Lacertae | 2642.3 9.8 Gi, 2661.4 10.2 Gi, 2683.4 11.9 Gi. |
| 225914 | RW Pegasi | 2707.5 11.6 Y. |
| 230110 | R Pegasi | 2639.3 12.0 Ja, 2659.4 11.7 Ja, 2679.5 11.2 Ro, 2684.5 10.7 Ro, 2684.5 *9.8* Jd, 2690.7 10.2 Bs, 2691.7 10.1 Bs, 2693.5 10.5 Jd, 2693.7 9.8 Bs, 2696.5 *10.1* Jd. |

VARIABLE STAR OBSERVATIONS, December 20, 1920 to January 20, 1921—Continued

| Number | Name | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 230759 | V Cassiop. | 2639.4 | 8.1 | Gi, | 2661.4 | 9.0 | Gi, | 2661.5 | 9.2 | Hs, | 2679.5 | 10.3 | Ro, |
| | | 2684.5 | 10.5 | Ro, | 2684.5 | 10.6 | Jd, | 2688.5 | 10.8 | Pt, | 2695.5 | 11.2 | Ro, |
| | | 2707.5 | 11.5 | Pi. | | | | | | | | | |
| 231425 | W Pegasi | 2685.2 | 10.5 | L. | | | | | | | | | |
| 231508 | S Pegasi | 2688.6 | 11.0 | Pt. | | | | | | | | | |
| 233335 | ST Androm. | 2635.0 | 10.7 | Ch, | 2637.0 | 11.4 | Ym, | 2643.0 | 10.8 | Ym, | 2643.2 | 10.0 | Ch, |
| | | 2655.9 | 10.3 | Ym, | 2682.5 | 10.0 | Gd, | 2688.6 | 10.2 | Pt, | 2690.6 | 9.0 | Hu, |
| | | 2707.5 | 9.6 | Pi. | | | | | | | | | |
| *233815* | R Aquarii | 2633.1 | 8.9 | Ch, | 2644.2 | 8.1 | Ch, | 2688.6 | 6.6 | Pt. | | | |
| 233956 | Z Cassiop. | 2701.6 | 13.7 | B, | 2707.5 | *11.4* | Pi. | | | | | | |
| 235053 | RR Cassiop. | 2639.5 | 13.9 | Gi, | 2661.4 | 14.0 | Gi. | | | | | | |
| *235209* | V Ceti | 2637.4 | 9.1 | Gi, | 2650.4 | 9.0 | Gi, | 2689.6 | 11.6 | Pt. | | | |
| 235350 | R Cassiop. | 2639.5 | 9.5 | Gi, | 2661.4 | 10.1 | Gi, | 2662.5 | 10.2 | Mt, | 2671.3 | 10.4 | Mt, |
| | | 2680.4 | 10.5 | Mt, | 2707.5 | 11.6 | Pi. | | | | | | |
| 235525 | Z Pegasi | 2647.5 | 12.7 | Ja, | 2664.4 | 12.8 | Ja, | 2689.6 | 12.5 | Pt. | | | |
| *235715* | W Ceti | 2639.4 | *13.2* | Gi, | 2661.3 | 14.0 | Gi. | | | | | | |
| 235855 | Y Cassiop. | 2642.4 | 10.0 | Gi, | 2661.4 | 9.8 | Gi, | 2698.6 | 10.2 | B. | | | |
| 235939 | SV Androm. | 2661.5 | 9.9 | Hs, | 2689.6 | 11.1 | Pt, | 2696.6 | 11.2 | Y, | 2701.6 | 11.8 | B, |
| | | 2707.5 | 12.0 | Pi. | | | | | | | | | |

Total Observations: 940. Stars: 199. Observers: 34.

blanks are intended for the reports sent for publication, the reports intended for predictions and permanent record should be sent to Harvard Observatory on the blanks provided by the Observatory. In order to avoid mistakes in preparing the reports, observers are requested not to use ditto marks for date of observation or magnitude.

The following are some of the interesting stars scheduled to reach maximum some time in March, the date being given with each star:

| | | Mar. | | | Mar. |
|---|---|---|---|---|---|
| 001755 | T Cassiop. | 27 | 053531 | U Aurigae | 17 |
| 004533 | RR Androm. | 12 | 095421 | V Leonis | 13 |
| 013338 | Y Androm. | 31 | 154615 | R Serpentis | 1 |
| 032043 | Y Persei | 21 | 161138 | W Cor. Bor. | 4 |
| 050003 | V Orionis | 31 | 175654 | V Draconis | 14 |

The Association continues to grow, and the Council announces that the following new members have been elected:

Mr. John Ellsworth, Lyon, France.
Sr. A. F. La Jara, San Juan, Porto Rico.
Mr. P. S. Watson, Baltimore, Md.

The following members of the Association have been honored with membership in the American Astronomical Society: Messrs. Barns, Godfrey, Shook, and Waldo.

The following members contributed to this report: Messrs. Barns, "Bs," Bouton, "B," Chandra, "Ch," Clement, "Cl," Eaton, "E," Furukawa, "Fk," Gartlein, "Ga," Ginori, "Gi," Godfrey, "Gd," Hall, "Hl," Miss Harwood, "Hw," Miss Hawes, "Hs," Horn, "H," Hunter, "Hu," Janczewski, "Ja," Jordan, "Jd," Johnson, "Jo," Kaster, "Ka," Lacchini, "L," McAteer, "M," Merrill, "Ml," Merton, "Mt," Mrs. Morris, "Ms," Mundt, "Mu," Peltier, "Pt," Pickering, "Pi," Reesinck, "Rk," Rhorer, "Ro," Schwartz, "Sz," Suter, "Su," Watson, "Pw," Yalden, "Ya," Yamamoto, "Ym," and Miss Young, "Y."

HOWARD O. EATON, Recording Secretary.

## COMMUNICATIONS.

**The Sun's Heat.** —In my reading on astronomical subjects I have been impressed with the difficulty which astronomers meet in trying to find a theory that will explain the source of the sun's heat and yet will allow the sun a length of life required by the geologists. The contraction theory seems to be the most popular today but even this is inadequate to account for the energy emitted by the sun if it is assumed that the sun gives off energy in every direction in an amount corresponding to that received by the earth. The amount of heat received by the earth is known with a fair degree of accuracy and it is the writer's understanding that the total amount of heat which the sun is supposed to emit is determined by comparing the area of the earth exposed to the sun's rays with the area of an imaginary sphere having for its radius the distance from the sun to the earth.

There is a question in the writer's mind, however, as to whether or not energy is actually drawn from the sun except where the heat or light rays impinge upon a body that is capable of converting these rays into what we might term perceptible heat. In other words, it may require but very little energy to maintain these light or heat rays under stress.

Energy is always the product of two factors, potential and mass. A steam pressure of three hundred pounds per square inch could be generated in a boiler the size of a tin fruit can, yet such a boiler would not operate the turbine of an ocean liner. Something more than pressure is required to supply the energy needed. The pull of gravity exerted upon the earth by the sun is enormous yet as long as this pull remains static, energy is not developed. Is it not possible that there is some unknown property of light and heat rays that corresponds to the above?

In other departments of physics there are a number of analogies which would suggest that this theory might be true, but I will mention only one, which, while somewhat crude, illustrates the idea.

An alternating current generator may be connected to a line supplying transformers of an aggregate capacity sufficient to greatly overload the generator, yet practically no energy will be required to maintain the voltage upon the supplying line of the secondaries of the transformers are unloaded. When, however, a load is placed upon the secondary side a corresponding load is immediately demanded of the generator.

If an analogous condition exists in connection with the sun's rays then energy is only demanded of the sun when its rays strike one of the planets; the amount of energy then required would be relatively small and almost any theory of the source of the sun's heat would allow a length of life commensurate with the geologist's requirements.

The writer has neither the knowledge nor the equipment to test the correctness of this theory and simply offers it as an interesting suggestion which others might develop if it is considered worth while.

271 Appleton St., Holyoke, Mass. ARTHUR J. NEWELL.

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**An Amateur's Telescope.**—The following description will make clear the construction of the telescope shown in the accompanying photograph:

The tube was made of galvanized metal in two lengths, one to fit inside of the other and not too tight to prevent sliding easily for focussing. In one end

of the tube were put two beadings (separated by a distance equal to the thickness of the lens on its circumference) the one farthest in the tube with the ridge inside and the one at the end with the hollow inside. The lens rests against the inner ridge and a split ring in the hollow of the outer beading holds the glass in place. On the other end of the tube a cap was fastened and a tube about an inch long was soldered in a hole in the center of this cap, in which a standard eye-piece would fit snugly. Inside of tube is painted dull black and half way between ends a diaphragm of cardboard is fitted in which is a hole whose diameter is about one-half of the objective.

TELESCOPE MADE BY ERNEST H. WEEKS.

The equatorial was built of a bicycle frame. The tubing leading from the crank hanger was cut off with the exception of the one leading to the seat. The front forks were cut off at the crown and the head tube was fitted to ball-bearings through the crank hanger and an iron rod fitted in the head tube to serve as a weight. As can be seen in the photograph, the seat post tube was mounted in wooden bearers as the hour axis the other axis being the degree axis. The cradle for the telescope, which is simple and can be made in several ways (the photo shows our method) was bolted to the crown of the forks with two bolts so that the telescope is parallel with the hour axis. Circles were made of wood and fitted to both shafts for hours and degrees.

The head of the tripod was made of quarter-inch iron cut in hexagonal

shape and three blocks of wood bolted edge-on with two bolts each. The legs were made of oak, ends cut to fit the blocks snugly and bolted.

The equatorial was mounted on the edge of a board as shown. Two uprights were bolted to a small square block spaced so the board holding the equatorial would fit between them and a bolt through the iron tripod head and up through the block holding the two uprights held the whole outfit in place.

For the above outfit we purchased two eyepieces and with the higher power we got very good observations of Saturn's rings. The low power eye-piece had a field lens of one and three-sixteenths inches aperture and the high power had an aperture of eleven-sixteenths.

More particular details will be given to any reader who may desire them.

ERNEST H. WEEKS.

Riverhead, N. Y.

## GENERAL NOTES.

**Dr. George Ellery Hale,** director of the Mount Wilson Solar Observatory, has been awarded the Actonian prize by the Royal Institution of Great Britain in recognition of his work on solar phenomena. *(Science,* February 18, 1921.)

**Harlow Shapley,** of the Mount Wilson Solar Observatory, has been appointed observer at the Harvard College Observatory, and will enter upon his new work in March or April. *(Science,* February 18, 1921.)

**The American Astronomical Society.**—The next meeting of the Society will be held at the Van Vleck Observatory, Wesleyan University, Middletown, Connecticut, from August 30 to September 2, 1921.

JOEL STEBBINS, *Secretary.*

**Astronomical Institute.**—At the University of Amsterdam an astronomical institute is being founded that will take up in the first place the investigation of our stellar universe and the galactic system, especially by means of the study of astronomical photographs.

**The North American Almanac** for 1920 has just made its appearance. It claims for itself the title of "The Aristocrat of Almanacs." There is justification for this in the following particulars: First, it is neatly bound in stiff covers; second, it omits from its pages the unscientific predictions of various kinds usually found in almanacs; third, its illustrations, insofar as they are astronomical, are made from photographs made at the Yerkes observatory and not from antiquated drawings. It contains a large amount of information on various topics, and sufficient spice to make it interesting to any reader. This is the first issue, and is published by the North American Almanac Co., Chicago.

**Officers of the Mathematical Association of America.**—At the meeting of the Mathematical Association of America, at the University of Chicago, December 28-29, the following officers were elected: President, Professor

G. A. Miller; Vice-presidents, Professor R. C. Archibald and Professor R. D. Carmichael; Board of Trustees, to serve till January, 1924, Professor A. A. Bennett, Professor Florian Cajori, Professor H. L. Rietz and Professor D. E. Smith. The Board chose Professor C. F. Gummer to fill the vacancy on the Board caused by the election of Professor Carmichael as vice-president. *(The American Mathematical Monthly*, February, 1921.)

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**Provisional Wireless Time Service.**—It is notified for general information that arrangements have been made for a provisional wireless time-service from the standard mean-time clock of the Hector Observatory (latitude 41° 17′ 03″.8 south, longitude 174° 46′ 04″ east of Greenwich), Wellington. This service was begun on October 1, 1920.

The time-signals are transmitted by the Wellington Radio-station (latitude 41° 16′ south, longitude 174° 46′ east of Greenwich) on a wave-length of 600 metres. The sending-key at the radio-station is automatically operated by the Observatory clock.

C. E. Adams.

Wellington, New Zealand.

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**The Satellites of Saturn.**—Probably every student of astronomy is familiar with the two ingenious Latin dactylic hexameters framed by the Rev. T. E. Espin (Webb's *Celestial Objects*, etc., 1ᵉ, p. 218, n. 2) to help beginners remember the names of the satellites of Saturn in their order from the planet outward. The verses did excellently until the discovery of two more satellites impaired their efficiency. I have therefore concocted the following triplet to include the ten satellites now known, using the former verses as far as they would go, that is, up to the place of Themis:

Ecce Mimas nitet, Enceladus Tethysque, Dione;
Inde Rhea et Titan, post quem Themis atque Hyperion;
Iäpetus mox, et claudit seriem ultima Phoebe.

If it were desirable to commemorate the fact that the motion of Phoebe is retrograde, the plane of her orbit being excessively inclined to that of the planet's equator, that might be easily done by one more hexameter, as follows (semicolon after Phoebe):

Transverse fugiens mire obliquum implicat orbem.

Elmer Truesdell Merrill.

The University of Chicago.

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**A New Asteroid.**—A cabelgram from M. G. Lecointe, Director of the Central Bureau of Astronomical Telegrams, at Bruxelles, announces the discovery of a planet by Comas Solá, of Barcelona, in the following position:

February 3.3274 G.M.T.
R.A. $9^h\ 17^m$
Dec. $+19°\ 20'$
Daily Motion, $1^m\ 44^s$ west; 13′ south.

The message indicates that a large telescope is necessary for observing the planet.

S. I. Bailey.

Harvard College Observatory Bulletin 740.
Cambridge, Mass., U. S. A., February 7, 1921.

**Ephemeris of Asteroid 1919 F. D. of the Trojan Group.**—On page 388 of the August 1920 number of *L'Astronomie* are some elements of what is apparently a new asteroid of the Trojan group. The elements are by Professor Cohn of the *Rechen-Institute*, Berlin. No statement is given as to how bright the asteroid is at opposition, etc. I have computed an ephemeris of this asteroid for the next opposition which will take place on April 12, 1921. It will be way south in the Centaur.

EPHEMERIS.

| G.M.T. 1921 | α h | m | s | δ ° | ′ | ″ | log *r* | log Δ |
|---|---|---|---|---|---|---|---|---|
| Mar. 15.5 | 13 | 39 | 45 | —32 | 11 | 2 | 0.74400 | 0.68048 |
| 19.5 | 13 | 37 | 46 | —32 | 17 | 15 | 0.74410 | 0.67703 |
| 23.5 | 13 | 35 | 47 | —32 | 21 | 52 | 0.74418 | 0.67403 |
| 27.5 | 13 | 33 | 40 | —32 | 24 | 42 | 0.74426 | 0.67138 |
| 31.5 | 13 | 31 | 27 | —32 | 25 | 45 | 0.74438 | 0.66915 |
| Apr. 4.5 | 13 | 29 | 9 | —32 | 25 | 2 | 0.74446 | 0.66725 |
| 8.5 | 13 | 26 | 47 | —32 | 22 | 42 | 0.74454 | 0.66573 |
| 12.5 | 13 | 24 | 23 | —32 | 18 | 48 | 0.74462 | 0.66467 |
| 16.5 | 13 | 21 | 58 | —32 | 13 | 6 | 0.74468 | 0.66397 |
| 20.5 | 13 | 19 | 35 | —32 | 6 | 2 | 0.74478 | 0.66379 |

F. E. SEAGRAVE.

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**Design of Mounting for a Globe to Illustrate Variation of Latitude.**—Everyone is familiar with the common terrestrial globe mounted in an iron ring. In order that it may be used to illustrate the "Variation of Latitude," the globe should be supported by two pins fastened to the iron ring at the opposite extremities of a diameter. On the globe at its poles should be fastened two thick metal plates, containing symmetrical grooves, into which the pins set. For the sake of simplicity the grooves might be elliptical, thus representing the annual component of the motion of the poles. If now we imagine the globe thus mounted, started to rotating in such a way that as it rotates, the pins will slide along the grooves, we will have a concrete illustration of the nature of this phenomenon.

WM. O. BEAL.

The University of Minnesota, Feb. 10, 1921.

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**Recent Parallax Work.**—Within the last few days three series of stellar parallax determinations have been received.

The first of these is Volume 3 of the *Publications of the Leander McCormick Observatory* of the University of Virginia. It gives the results of five years' work on the determination of parallaxes by the photographic method by the observatory staff. Over 8,000 photographic exposures were made with the 26-inch refractor. The measurement and reduction of this great amount of observational material yielded parallaxes of 260 stars. The probable error of these parallax values is stated to be ± 0″.009.

The second is an article by Messrs. J. Jackson and H. H. Furner in the *Monthly Notices* of the Royal Astronomical Society for November, 1920. This paper is on the "Hypothetical Parallaxes of Visual Double Stars." In the investigation of double star orbits there is an equation involving the masses of the two components the semi-major axis of the orbit, the parallax of the system and the period. By solving this equation for the parallax and making assump-

tions as to the combined mass of the double star components the hypothetical parallaxes of nearly 600 double stars are obtained.

The third is a series of 49 parallaxes determined photographically with the 26-inch refractor of the Royal Observatory at Greenwich and is published in the same number of *Monthly Notices* as the preceding. The 758 plates were taken between 1913 and 1920 to determine these 49 stellar distances.

These three series of parallaxes will be welcomed by all those whose work requires a knowledge of the distances of the stars.

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**Radial Velocity Catalogue.**—A "First Catalogue of Radial Velocities" by J. Voute of Java, Dutch East Indies, has just been issued. In this publication the author has compiled a list of the radial velocities of over 1900 stars and of 148 nebulae and clusters, thus bringing together material scattered through various publications. A catalogue of this nature will be of value for various statistical studies as it contains not only the radial velocity with the name of the observatory making the observations but also the magnitude, proper motion, type of spectrum, parallax when known, and the galactic latitude and longitude for each object listed.

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**Proposed Station for "Solar-Constant" Work in Arizona.**—The prevailing cirrus cloudiness and haziness at Mount Wilson in all recent years, greatly exceeding that which obtained from 1905 to 1910, when the station was new, has been very discouraging. Furthermore, the station is quite unsuitable for "solar-constant" work in winter and spring months owing to cloudiness. It is urgently desirable to observe the solar radiation daily, as far as possible, in the United States, in order to check the results which are being obtained by Smithsonian observers in Chile.

Accordingly it seemed best to set up a station in the most cloudless region of the United States, where the work could go on during the entire year. Chief Marvin, of the Weather Bureau, obligingly caused investigations to be made of various proposed sites in California, Nevada, and Arizona. The one of highest promise appeared to be on the Harqua Hala Mountain (elevation about 5,800 feet) near Wenden, Ariz. Congress was urged to appropriate $25,000 for the establishment of a first-rate "solar-constant" observing station at the best site, but the appropriation failed.

At this juncture Messrs. Abbot and Marvin held a long discussion by correspondence and verbally as to the reality of the supposed solar variability, and its availability as a forecasting element, in view of the use being made of the Smithsonian solar observations in Chile by the Argentine and Brazilian weather bureaus. The discussion brought out very clearly the urgency of obtaining corroborative observations of the solar radiation daily in the United States.

Fortunately the proposed new station obtained private financial support in the lack of congressional action. Mr. John A. Roebling, of Bernardsville, N. J., at Dr. Abbot's solicitation, made a grant of $11,000 for promoting measurements of solar radiation. Mr. Roebling made the condition that so much of this sum as necessary should be devoted to removing the Smithsonian station from the plain near Calama, Chile, to a mountain site above the reach of dust and smoke. Any balance remaining after this improvement of the Chilean station could be used for the removal of the Mount Wilson equipment to the Harqua Hala Mountain in Arizona, or for such other purpose as Dr. Abbot might prefer for the advance of the study of solar radiation.

At a cost of between $4,000 and $5,000 the Calama station was removed to a mountain about 10 miles south of Calama, where skies of extraordinary purity have been experienced. The removal was completed and first observations made at the mountain shortly after the close of the fiscal year.

Dr. Abbot visited Wenden, Ariz., and the Harqua Hala Mountain in the last week of June, 1920. Contracts were made for the erection on the summit of a stone and adobe building of two stories, a lower, partly underground, for observing, and an upper for quarters of observers. This is to be ready for occupancy by September 15, 1920, when it is proposed to remove the "solar-constant" observing equipment from Mount Wilson to Harqua Hala. (From the *Annual Report of the Smithsonian Institution*, 1920, pp. 93, 94.)

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**The Bright Rays on the Moon.***—Whoever has observed the full moon by means of a telescope, even though a small one, will have wondered at the bright rays which emanate from various regions and particularly from Tycho. These rays are not always visible—only at the time of full moon do they reveal themselves in their full brilliancy. They extend to great distances across the surface of the moon, in some cases hundreds of kilometers. Their greatest peculiarity is their rectilinear character: they extend across plains, over mountains and valleys, across craters and all other inequalities of surface. As an explanation it is often assumed that the moon, while cooling, had had its crust broken in the weaker places, and that the openings formed in this way had been filled from beneath by molten material of high reflecting power comparable to quartz. Such a fissure would appear as a bright ray in marked contrast to its surroundings when illuminated by the sun's rays falling nearly vertically upon it.

Have we, perhaps, formations upon the earth which, in origin and appearance, show similarity to the lunar rays: rectilinear character for many kilometers; small width; material of high reflecting power? We find characteristics of this sort in the so-called pile formations in the old mountain mass along the Bavarian-Bohemian boundary, especially at Pfahl in the Bavarian Forest. This formation extends in a straight line from Roding in a NW-SE direction to the Bohemian border near Klafferstrass. It can be followed for a total distance of about 150 kilometers. The white rock of the Pfahl quartz often can be found in pure form. If our planet were observed from the moon this filled fissure, wherever it appears on the surface, would clearly appear as a white streak in strong contrast to the remaining surface because of the high reflecting power of the white rock under a high sun—probably just as we inhabitants of the earth behold the bright rays on the moon.

PROFESSOR K. STOECKL.

*Translated from "Die Himmelswelt," **30**, 26, 1920.